APPENDIX C - LIFE CYCLE COST BASIS PARAMETERS

Values from the Ameren 10-13-2017 NPV / CPWRR Model

	Average Net Capability (Mw)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Load Reduction Costs, $/mwh of Outage, Random Day		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Labadie 1	602	$ 6.107	$ 5.455	$ 5.342	$ 5.595	$ 8.009	$ 8.913	$ 8.915	$ 9.228	$ 9.506	$ 9.517	$ 9.888
Labadie 2	599	$ 6.190	$ 5.522	$ 5.407	$ 5.672	$ 7.595	$ 8.558	$ 8.425	$ 8.721	$ 8.981	$ 9.000	$ 9.330
Labadie 3	616	$ 5.571	$ 4.959	$ 4.886	$ 5.187	$ 7.192	$ 7.985	$ 7.757	$ 8.041	$ 8.315	$ 8.313	$ 8.635
Labadie 4	616	$ 6.160	$ 5.501	$ 5.385	$ 5.648	$ 7.712	$ 8.535	$ 8.353	$ 8.648	$ 8.911	$ 8.935	$ 9.269
Labadie Common	2,433	$ 6.005	$ 5.357	$ 5.254	$ 5.524	$ 7.625	$ 8.495	$ 8.359	$ 8.656	$ 8.924	$ 8.938	$ 9.277

Valuation of Capacity & Energy (Forward Market Curve)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Forward Market Curve Energy Price - All Hours 7x24 ($/Mwh):	$ 25.95	$ 25.77	$ 25.87	$ 26.29	$ 29.29	$ 30.50	$ 30.65	$ 31.22	$ 31.96	$ 32.30	$ 33.50
Regulated Capacity ($/kw):	$ 8.98	$ 18.50	$ 59.99	$ 92.17	$ 96.25	$ 96.64	$ 96.24	$ 96.61	$ 97.84	$ 99.11	$ 99.89

Load Reduction Costs, $/mwh of Outage, Random Day		2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Labadie 1	602	$ 10.288	$ 10.913	$ 11.658	$ 12.615	$ 13.287	$ 13.855	$ 14.502	$ 15.387	$ 15.892	$ 16.565	$ 17.238
Labadie 2	599	$ 9.728	$ 10.320	$ 11.025	$ 11.938	$ 12.573	$ 13.112	$ 13.731	$ 14.570	$ 15.051	$ 15.690	$ 16.330
Labadie 3	616	$ 9.014	$ 9.590	$ 10.272	$ 11.165	$ 11.775	$ 12.300	$ 12.910	$ 13.732	$ 14.190	$ 14.812	$ 15.433
Labadie 4	616	$ 9.660	$ 10.254	$ 10.954	$ 11.858	$ 12.484	$ 13.022	$ 13.645	$ 14.491	$ 14.959	$ 15.595	$ 16.232
Labadie Common	2,433	$ 9.668	$ 10.265	$ 10.973	$ 11.890	$ 12.525	$ 13.067	$ 13.692	$ 14.540	$ 15.018	$ 15.660	$ 16.303

Valuation of Capacity & Energy (Forward Market Curve)	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Forward Market Curve Energy Price - All Hours 7x24 ($/Mwh):	$ 34.74	$ 36.02	$ 37.35	$ 38.74	$ 40.17	$ 41.65	$ 43.20	$ 44.79	$ 44.24	$ 45.30	$ 46.36
Regulated Capacity ($/kw):	$ 101.77	$ 102.04	$ 102.98	$ 103.91	$ 104.84	$ 105.77	$ 106.70	$ 107.63	$ 108.56	$ 109.49	$ 110.42

Load Reduction Costs, $/mwh of Outage, Random Day		2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Labadie 1	602	$ 17.911	$ 18.584	$ 19.257	$ 19.930	$ 20.603	$ 21.276	$ 21.949	$ 22.622	$ 23.294	$ 23.967	$ 24.640
Labadie 2	599	$ 16.969	$ 17.609	$ 18.249	$ 18.888	$ 19.528	$ 20.167	$ 20.807	$ 21.447	$ 22.086	$ 22.726	$ 23.365
Labadie 3	616	$ 16.055	$ 16.677	$ 17.298	$ 17.920	$ 18.542	$ 19.163	$ 19.785	$ 20.407	$ 21.029	$ 21.650	$ 22.272
Labadie 4	616	$ 16.868	$ 17.505	$ 18.142	$ 18.778	$ 19.415	$ 20.051	$ 20.688	$ 21.325	$ 21.961	$ 22.598	$ 23.234
Labadie Common	2,433	$ 16.945	$ 17.588	$ 18.230	$ 18.873	$ 19.516	$ 20.158	$ 20.801	$ 21.443	$ 22.086	$ 22.728	$ 23.371

Valuation of Capacity & Energy (Forward Market Curve)	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Forward Market Curve Energy Price - All Hours 7x24 ($/Mwh):	$ 47.41	$ 48.47	$ 49.53	$ 50.58	$ 51.64	$ 52.70	$ 53.75	$ 54.81	$ 55.87	$ 56.92	$ 57.98
Regulated Capacity ($/kw):	$ 111.35	$ 112.28	$ 113.22	$ 114.15	$ 115.08	$ 116.01	$ 116.94	$ 117.87	$ 118.80	$ 119.73	$ 120.66

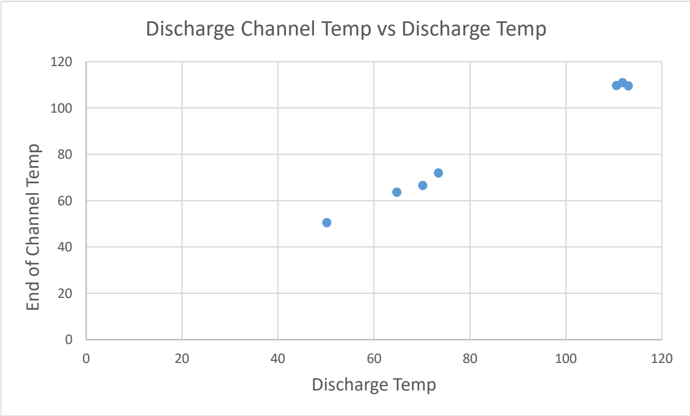
1. Value of Capacity, Value of Energy, and Load Reduction Costs are based on economic forecasts for energy prices (LMP) and fuel costs and other variable O&M costs at Labadie.

Basis Dispatch Profile, % Hours

Percent Hours for Summer Peak	10%
Percent Hours for Summer Avg	35%
Percent Hours for Winter/Ann Avg	55%

APPENDIX D – DISCHARGE CHANNEL TEMPERATURE REDUCTION

Date	River Flow at Labadie Upstream of Facility Intake (cfs)	Background River Temperature (^oF)	Facility Discharge Flow (cfs)	Facility Discharge Temperature (^oF)	Temperature (^oF) at End of Discharge Channel	Channel / Discharge
July 31 – August 1, 2003	43,219	83.7	2,033	110.6	109.7	0.992
25-Aug-03	35,478	83.4	1,988	113.05	109.6	0.969
14-Jan-04	41,391	36.3	1,586	70.24	66.5	0.947
14-Jan-16	164,021	36.1	1,839	50.2	50.5	1.006
28-Jan-16	110,656	34.8	1,895	64.8	63.6	0.981
1-Apr-16	80,281	53.2	1,569	73.5	72	0.980
25-Jul-17	68731	86.5	2162	111.86	111.02	0.992



Average	84.893	83.274	**0.981**	**<<< Temp at end of channel is aproximately 2% less than discharge temp**
Min	50.2	50.5	0.947	
Max	113.05	111.02	1.006	
Std Dev	26.245	25.919	0.019	
CV	0.309	0.311	0.019	
Average Summer	111.84	110.11	**0.985**	**<<< Temp at end of channel is aproximately 1.5% less than discharge temp during summer conditions**

CREATE AMAZING.

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Appendix B

RESUME

JOHN M. BURNS, PRESIDENT
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www.BurnsEngr.com

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FAX: 978 887 1169

Experience Summary

Mr. Burns has over 50 years of experience in engineering. In mid 1998 he founded Burns Engineering Services Inc., an engineering consulting company that mainly specializes in the improvement of power plant cooling systems and the technology of condensers and cooling towers. He is its President and Director of Engineering. His broad engineering experience provides a unique overview of the entire cooling system and how its components interrelate and affect turbine generation. Since founding this new company, he and his Company have assisted over 60 utilities, architect-engineers and equipment manufacturers in diverse engineering efforts that relate to cooling systems, cooling towers and condensers. These services were furnished to installed and planned condensers and cooling towers of combined-cycle, fossil, geothermal, and nuclear plants ranging from 10 to 1400 MW in the U.S., Canada and the UK.

Mr. Burns is a nationally known authority in the area of cooling systems, cooling towers and condensers.

In general, the power plant engineering, evaluations, reports and design work of Burns Engineering Services have been related to all systems, components and hardware located downstream of the turbine flange joint with the condenser. This work has included:

Cooling system poor performance and troubleshooting mechanical problems; dry and wet closed-cycle cooling system retrofits, their furnish & erect specifications and alternative cost estimates & generation impacts for both new and existing stations; retubing studies and projects, extended power uprate studies associated with the cooling system; visual inspections; numerous condenser finite element analyses to estimate stresses, loads and deflections; cooling equipment cost estimates; predictions of the potential for condenser tube vibration and damage- particularly as a result of the operation of bypass spargers on combined-cycle plants; modular condenser specifications; condenser retubing specifications, tube material evaluations and recommendations; tube corrosion problems, tubesheet field evaluations; steam jet air ejector (SJAE) field performance troubleshooting and design evaluations; condenser field performance testing; the evaluation of condenser hardware modifications; bid analysis of condensers, cooling towers, wet surface air cooled condensers and natural draft dry cooling systems; hydraulic analyses; 316(b) studies concerning once-through, dry and wet cooling system and equipment design and cost estimates; related engineering and environmental reports; cooling system related testimony and expert reports; and seminars.

From 1974 to 1998, he was employed as a titled Consultant in the Mechanical Division of the Stone & Webster Engineering Corporation of Boston, Massachusetts. That company had been the Engineer, Purchase & Construct (EPC) contractor for about 1,000 power plants throughout the world. There he specialized in similar cooling system work and equipment evaluations as was indicated in the previous paragraph with a greater emphasis on new plants, new cooling systems, new equipment and thermal insulation.

Before joining Stone & Webster in 1974, Mr. Burns was employed for about 14 years by the Condenser Division of the Ingersoll Rand Co., a major condenser, ejector and vacuum refrigeration equipment manufacturer that is now SPX, Yuba. Initially he was an engineer in the design group of the Division and ultimately he became its hands-on Manager of Engineering Development. He and his group were responsible for shop testing, computer programming, the development of a natural draft cooling tower & a direct contact condenser, condenser design improvements, hydraulic and air test modelling, troubleshooting, SJAE and condenser field testing.

Throughout his career, Mr. Burns as served on several committees of the American Society of Mechanical Engineers (ASME): he is the Chairman of ASME PTC 23, the Cooling Tower Test Code Committee that in 2003 completed and published an expansion of this ASME national test code standard encompassing many new types of wet tower testing;

Chairman of ASME PTC 12.2, the Condenser Test Code Committee that was issued in 1998 as the national standard then and Chair of the subsequent PTC 12.2 test code effort that was published as the national standard in 2010; and Chairman of ASME PTC 30.1 on Air Cooled Steam Condensers, a new test code effort that was published in 2008. In addition, since 1992, Mr. Burns has been a participating Member of the ASME Standards Committee on Performance Test Codes that overviews the entire ASME test code program. In this latter capacity he was the Liaison member on Verification & Validation Guidelines in Computational Solid Mechanics and PTC 24, Steam Jet Air Ejectors; he was also a former member of the Honors & Awards Subcommittee.

Mr. Burns has authored or co-authored approximately 40 papers and articles within his field of power plant cooling systems and the technology of condensers and cooling towers.

Mr. Burns is also familiar with more general applications of heat transfer and has utilized radiation, convection and conduction in power plant situations. He developed the criteria analysis used by Stone & Webster in nuclear plant design for the separation of hot pipe from electrical conduit. While at Stone & Webster, besides the cooling system specialty, for several years he was responsible for providing projects with estimates of various kinds of insulation applied to piping and equipment in fossil plants, nuclear balance-of-plant and containment areas.

Awards

ASME 2002 Dedicated Service Award, April 2002
ASME 2002 Performance Test Codes Medal, November 2002
Elected an ASME Fellow-1998; Life Fellow, 2004

Education

M.S., Mechanical Engineering - Lehigh University, Bethlehem, Pennsylvania - 1962
B., Marine Engineering - New York Maritime College, Bronx, New York - 1958

Training

Linear Finite Element Stress Analysis, Algor Inc – ‘98, ‘99,’03, ‘06 and ’09 - 2 & 3 day Seminars
Finite Element Stress Analysis, ASME - 1983, 3 day Seminar
Failure Analysis, ASME - 1982, 3 day Seminar

Licenses, Registrations, and Certifications

Professional Engineer, New York, 41117 - 1964, Active
Professional Engineer, New Jersey, 17383 - 1972, Active
Professional Engineer, Massachusetts, 36673 - 1992, Active
Professional Engineer, Texas, 97181- 2006, Active
Professional Engineer, Minnesota, 53260 - 2016, Active
Marine, Third Assistant Operating Engineer, Steam & Diesel, -U.S. - 1958, Inactive
Stationary, Blue Seal Operating Engineer, New Jersey - 1960, Inactive

Professional Affiliations

Mr. Burns has been active in the ASME Codes and Standards Division since 1971.

ASME Standards Committee on Performance Test Codes, Member since 1992 - Active

As a Member, he contributes to the direction of all 50 ASME performance codes. Mr. Burns is currently the Board Liaison for the Verification and Validation Committee on Computational Solid Mechanics and Steam Jet Air Ejectors.

ASME PTC 30.1 (Air Cooled Steam Condensers), Chairman, Active

He assisted in developing PTC 30 for general Air Cooled Heat Exchanger testing which was issued in 1991. In 2003, at the direction of the ASME Board, he organized a new fast-track test code effort that was focused on developing technology for the performance testing of dry, air cooled steam condensers. With his direction, its 15 Members have cooperatively written this new test Code that was published in June 2008 and is now the national standard.

ASME PTC 23 (Cooling Towers), Chairman, Active

As Vice Chair, he was instrumental in publishing the old 1986 Code. He reorganized a new 12-member committee in 1995. With their cooperation and help, he led a fast-track effort to develop and publish an all inclusive Code document for both wet/dry plume abatement test compliance, thermal performance of wet mechanical and natural draft towers, evaporative coolers and wet-surface air cooled condensers. The Code was published as the ANSI/ASME national test standard in 2003.

ASME, PTC 12.2 (Condensers), Chairman, Active

From 1989 to 1998 he contributed technically as he motivated a 13 member committee to develop a practical, cost effective, accurate, and modern Code. Under his guidance and direction, this new ANSI/ASME national standard was published in 1998. He is Project Leader and contributor to formal Technical Inquiries on PTC 12.2 interpretations as they occur. He also was chosen to Chair the subsequent condenser test Committee and with an innovative perspective on the basis of the tests, led that effort to further streamline and improve this Code. This Code was published in 2010 and is the new national ANSI/ASME condenser performance test code.

ASME Cooling Tower Research Committee, 1984 to 1989, Past Member

He developed the committee position on tower siting and contributed to other resolutions at that time.

Cooling Tower Institute (CTI), 1986 to 1988, Past Director; 1986 Institute Officer;

Past Member of Water Flow Committee and Tower Upgrading Committee. As a Director and Officer, he participated in the executive actions necessary to maintain the viability of a 500-company roster within the cooling tower related industry.

Patents

Improved Direct Contact Condenser, 1975; this direct contact condenser improvement consists of more compact and efficient hardware to perform the heat transfer.

Condenser Air Inleakage Meter, Patent issued July 2011.

Two Patents on Apparatus and Method of Improving the Performance of Certain Large Condensers by Enhancing the Existing Design Hardware. Patents Awarded in 2014.

Security Clearances

Department of Defense, Top Secret - 1963, Inactive

Computer Hardware/Software Capabilities

Excel, Word, PowerPoint, Algor Finite Element Analysis Software,

Lectures

Main instructor of the Burns Engineering Services Seminar on Condenser Design, Maintenance & Operation. This two-day seminar has been given every winter in New Orleans or elsewhere and periodically around the U.S. and Canada from 2004 to 2017 and has had approximately 450 participants.

Lecturer on condensers in 2017 at Minneapolis, MN, Electric Power Research Institute (EPRI) Condenser Technical Seminar; about 60 attendees.

Lecturer at EPRI Condenser Technical Seminar, Denver, CO, August 2014; about 60 attendees.

Instructor at EPRI, Combined-Cycle Group, two-day seminar on condensers, Tucson, AZ, December 2014. About 60 attendees.

Instructor on condenser performance for two hours at Industry Conference, Condenser Life Cycle Seminar, Georgia Tech Conference Center, Sept 2010, 2011, & 2013. About 100 engineers have attended each lecture.

Instructor at EPRI, PE2P Nuclear Group, one day seminar on condensers, St. Louis, Il, 2013. About 60 attendees.

Instructor for the US AID Greenhouse Gas Emissions Reduction Project for NTPC in NOIDA, India on Condenser Design, Maintenance & Operation. About 60 engineers from the entire country attended the four- day seminar and plant inspection; October 2007.

Instructor for the CSA sponsored Condenser Air & Water Leak Detection Seminar to PREPA, at South Coast Plant, Puerto Rico, June 7, 2004. (About 20 operators & engineers from the PREPA system attended the Seminar.)

Instructor for 1.5 hour at EPRI Condenser Technology Seminar at the national 2011 Condenser Seminar and Conference at Chicago, IL and in August 2014 at Denver CO. About 100 engineers in attendance.

Instructor for 2 hours at EPRI Condenser Technology Seminar at the national 2008 Condenser Seminar and Conference at St Petersburg, FL in August, 2008. About 100 engineers were in attendance.

Instructor for the Condenser Design and Construction Section of the 2005 & 2002 EPRI Condenser Technology Seminar Course in San Antonio, TX, September 10, 2002 and in 2005, San Diego, CA (Over 90 engineers attended each session of the Seminars.)

Instructor for the Combined–Cycle Turbine Thermodynamics and Wet & Dry Cooling System Sections of the Educational Seminar for the Cooling Technology Institute Annual Conference, Corpus Christi, Texas, February 2001. (Over 150 engineers attended the Seminar.).

Instructor for the Thermal and Mechanical Design Sections and the Performance Test Code Section of the EPRI Condenser Technology Seminar Course, Charleston, SC, August 30-31, 1999. (Over 60 engineers attended the Seminar.).

The Instructor for the Dept. of Energy (DOE) sponsored Condenser Performance Workshop in NOIDA, India at the NTPC Training Center during week of April 26-30, 1999. (Over 60 engineers from all Indian States attended this seminar.).

Instructor of the Stone & Webster Company Training Session at the Denver Office entitled, “Condenser & Cooling Tower Application Engineering,” Denver, November 1997.

Instructor for the EPRI sponsored Condenser Technology Seminar Course entitled, “Condenser Design & Construction” and “Field Modifications,” Boston, MA, August 1996.

Instructor of the Stone & Webster Company Training Session entitled, “Condenser & Cooling Tower Application Engineering,” Boston, November 1996.

Co-instructor for the EPRI sponsored course to NRC Inspectors entitled, "Heat Exchanger Performance Prediction,” Chattanooga, TN, March 14-16, 1995.

Co-instructor for the EPRI sponsored course to utilities entitled, "Heat Exchanger Performance Prediction,” Philadelphia, Pennsylvania, June 21 - 23, 1994.

Instructor of a two-hour discussion on condenser steam sparger design to visiting Chinese engineers at Stone & Webster in May 1994.

Publications

Burns D., Burns J., Burns J., Stevens R., “Required Tasks & Engineering When Planning to Retube a Condenser with Thin-Walled Corrosion Resistant Tubing”, presented at EPRI Condenser Technology Conference, Minneapolis MN, July 2017.

Burns, D., Burns, J., Burns, J., Stevens, R., “Understanding Condenser Air Removal Systems Can Lead to Lower Turbine Backpressures”, presented at EPRI Condenser Technology Conference, Denver CO., August 2014.

Burns, J., Korellis, S., Martz, S. "Tests to Identify the Best Instruments and Locations for Accurate Condenser Pressure Measurements', presented at EPRI Condenser Technology Conference, Denver CO., August 2014.

Burns, D., Burns, J., Burns, J., Stevens, R., "Modular Condenser Replacements: Sizing Specifying and Analyzing the Bids", EPRI Condenser Technology Conference, 2011.

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Burns, D., Burns, J., Burns, J., Stevens, R., "Condenser Inspections and Performance Evaluations: Keys to Unlocking a Station's Full Potential", EPRI Condenser Technology Conference, 2008.

Burns, D.C., Sorenson, E, Lawrence, B, Stevens, R.L., Burns, J.M. & Burns, J.S; "Improving the Reliability of a BWR Through Condenser Condition Assessment", EPRI Condenser Technology Conference, 2005.

Burns, J.M., Burns, D.C., Burns J. S.; "Estimates Required to Achieve the Next Level of CWA 316(b) Compliance", presented at the International Joint Power Generation Conference, Electric Power, March 2004.

Burns, J. M.; "The Cost and Feasibility of Backfitting Cooling Towers at an Exiting Power Plant-An Industry Consultant Perspective", Shaw 316(b) Conference, September 30, 2003. (Presentation)

Burns, J. M., Burns, D. C., Burns, J. S., Stevens, R. L., Micheletti, W. C.; "Estimating Power Plant Cooling Tower Retrofit Costs & Impacts On Generation", presented at EPRI Cooling Tower Technology Conference, August 2003.

Burns, J. M., et al (7 Committee Member Co-authors); "ASME PTC 23-2003:The New Alternative For Accurate Cooling Tower Performance Testing", presented at EPRI Cooling Tower Technology Conference, August 2003.

Karg, D.C., Burns, J. M., Catapano, M.C.; "Application of the New ASME Performance Test Code on Steam Surface Condensers, PTC 12.2-1998", presented at the International Joint Power Generation Conference, June 2003.

Micheletti, W.C., Burns, J.M.; "Estimating Energy Penalties For Wet And Dry Cooling Systems At New Power Plants", EPA Symposium on Technologies for Protecting Aquatic Organisms from Cooling Water Intake Structures, May 2003.

Burns, J., Korellis, S.; "Features of ASME Condenser & Cooling Tower Performance Test Codes Will Identify Cost-Effective Improvements", EPRI Heat Rate Improvement Conference, 2003.

Burns, D.C., Stevens, R.L., Burns, J.M.; "Power Uprate; The Engineering Evaluation of the Condenser and Cooling Tower", EPRI Condenser Technology Conference, 2002.

Rhodes, N.; Hardy, C.A.; Burns, J.M.; Madden, T.B.; "CFD Analysis Predicts Condenser Performance After Large Power Uprate of the Quad Cities and Dresden Condensers", EPRI Condenser Technology Conference, 2002.

Karg, D.C.; Burns, J.M.; Catapano, M.C.; "Experience Evaluating Condenser Performance and Tube Fouling with the ASME Performance Test Code On Steam Surface Condensers, PTC 12.2- 1998", EPRI Condenser Technology Conference, 2002.

Micheletti, W.C. and Burns J.M.; "Emerging Issues and Needs in Power Plant Cooling Systems"; DOE Workshop, Pittsburgh, PA, July 2002.

Burns, J. M.; ASME Performance Test Codes Briefing, 2001 ASME University Mechanical Engineering Department Heads Meeting, ASME Annual Meeting, November 2001. (Presentation)

Micheletti, W. C. and Burns, J. M.; "Understanding Wet and Dry Cooling Systems", International Water Conference, October 2001.

Burns, J. M. and Tsou, J. L.; "Modular Steam Condenser Replacements Using Corrosion Resistant High Performance Stainless Steel Tubing", ASME International Joint Power Generation Conference, June 2001.

Burns, J.M. and Michelletti, W.C.; "Comparison of Wet and Dry Cooling Systems for Combined Cycle Power Plants"; Filed in Federal Register on Behalf of Utility Water Act Group, November 10, 2000.

Burns, J. M and Burns, D. C.; “Accurate Condenser Performance Tests”, ASME International Joint Power Generation Conference, 2000. (Presentation)

Burns, J. M.; Burns, D. C.; Burns, S. J.; “Structural Simulations of Condensers Using Finite Elements Furnish an Effective Field Repair or Design Basis”, EPRI Condenser Technology Conference, 1999.

Burns, J. M. and Haynes, C.J. ; “The Application and Benefit of Insulating Extraction Lines and Heaters Within the Turbine-Condenser Steam Space”, EPRI Heat Rate Improvement Conference, 1998.

Burns, J. M. and Haynes, C.J. ; “Why Extraction Lines and Heaters in the Turbine-Condenser Steam Space Should be Lagged”, International Power Generation Conference, 1998.

Burns, J.M.; Godard, D.; Randall, R.; Cooper, J.; “Justifying Plans to Improve the Performance of An Existing Cooling System,” EPRI Condenser Technology Conference, 1996.

Burns, J.M.; Panelist – “Incorporating Performance Test Codes Into Procurement Documents”, International Joint Power Generation Conference, 1996.

Burns, J.M.; Hernandez, E.; "Turbine Exhaust Pressure Measurement," EPRI Heat Rate Improvement Conference, May 1996.

Burns, J.M.; Hernandez, E.; "Comparison of An Alternative to the PTC 6 to Basket Tip Design,” International Joint Power Generation Conference, 1995.

Burns, J.M.; Nicholson, J.M.; Annett, J.H.; and Alexander, D.N.; "The Impacts of Retrofitting Cooling Towers at a Large Power Station.” , EPRI Cooling Tower Conference, August 1994.

Burns, J.M.; Almquist, C.; Hernandez, E.; Tsou, J.; "Accurate Condenser Performance Monitoring Guidelines Provided by New ASME Condenser Test Code.", EPRI Heat Rate Improvement Conference, May 1994.

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Burns, J.M.; Almquist, C.; Hernandez, E.; Tsou, J.; and Yost, J.; "The 1993 Revision of ASME PTC 12.2- A Better Condenser Test Code Suited for the '90's.", EPRI Condenser Symposium, September 1993.

Burns, J.M.; Panelist – “Heat Exchanger Testing”, National Heat Transfer Conference, August 1992.

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Burns, J.M.; Almquist, C.; Hernandez, G.; Tsou, J.; and Siewert, R.; "Improved Test Methods, Modern Instrumentation, and Rational Heat Transfer Analysis Proposed by Revised ASME Surface Condenser Test Code, PTC 12.2." 1991 ASME International Joint Power Generation Conference.

Bhayana, G.; Burns, J.M.; and Myatt, L.; "Modern Analysis Provides Repair Basis for Condenser Waterbox Cracks." 1991 ASME International Joint Power Generation Conference.

Burns, J.M.; Titus, P.; and Phillips, R.; "The Practical Application of Finite Element Stress Analysis to Problems of Operating Steam Condensers." 1990 EPRI Condenser Technology Conference.

Stevens, R.; Burns, J.M.; Curtis, C.; Grimm, G.; and Medina, C.; "Condenser Inspections: Valuable and Cost Effective." 1990 EPRI Condenser Technology Conference.

Burns, J.M.; Bhayana, G.; and Myatt, L.; "Waterbox Cracks - Analysis and Repair." 1990 ASME Joint Power Generation Conference.

Burns, J.M.; "Steam Condensers and Cooling Towers." 1989 ASME Plant Services Seminar, Houston and Dallas Stone & Webster.

Burns, J.M.; Corsi, L.; and Stevens, R.; "Modular Surface Condenser Retubing Considerations." 1989 ASME Joint Power Generation Conference.

Mussalli, Y.; Burns, J.M.; and Kasper, J.; "Upgrading Circulating Water and Condensate Systems for Improved Operation." 1988 SWEC Power Plant Improvement Seminar.

Yost, J.; Burns, J.M.; and Roma, F.; "Condenser Tube Heat Transfer Testing - An Alternate Approach to ASME PTC 12.2." 1986 ASME Joint Power Generation Conference.

Burns, J.M. and Brocard, D.; "Cooling Towers," Section 4.8. Handbook of Energy Systems Engineering: Reference text, J. Wiley & Sons, N.Y., 1985.

Kosten, H.; Burns, J.M.; Curlett, P.; and Morgan, J.; "Operating Experience and Performance Testing of the World's Largest Air Cooled Condenser." American Power Conference 1981.

Wilbur K. and Burns, J.M.; "An Examination of the Evolution and Substantiation of ASME's Proposed Test Code on Atmospheric Water Cooling Equipment." 1979 ASME Winter Annual Meeting.

Appendix 10 D. Black & Veatch – Ameren Fine Mesh Screen Evaluations and Conceptual Cost Estimates for the Labadie, Rush Island, and Sioux Power Plants

BLACK & VEATCH CORPORATION
TECHNICAL MEMORANDUM

Ameren	B&V Project 193718
Fine Mesh Screen Evaluations and Conceptual Cost Estimates for the Labadie, Rush Island, and Sioux Power Plants	B&V File 42.0000
	November 4, 2016

To: Mr. Matthew Molitor

From: Mr. Jim Singleton, Mr. Aaron Lemke, and Mr. Tom Ratzki, P.E.

This memorandum will cover the following scope of services:

- Screen sizing for 316(b) compliance
- Screen Manufacturers quotations
    - Advantages and disadvantages of the different screening technologies examined.
- Conceptual arrangements of the screen installations
- Budget level cost opinions
- Overall EPC delivery cost opinions

Screen Sizing for 316(b) Compliance

There are two basic methods of compliance with the Clean Water Act 316(b) requirements. The first method is to use the Best Technology Available (BTA) with fish friendly screens and fish return systems along with study of the effectiveness and survivability of the system for returning fish to the source water body. The second method is to provide sufficient screen area to provide a through screen velocity of less than 0.5 ft/s. This option is extremely expensive for the retrofit into the existing intakes and is not examined in detail as part of this memorandum because of the restricted space. Since the new screens will have a smaller opening size than the existing screens, the headloss through the screen is greater than the existing screens and causes some additional head on the existing circulating water pumps. Table 1-1 summarizes the headloss through the screens for the different technologies. The average loss through the screens is provided for comparison to the existing screen headloss.

Table 1-1 Summary of headloss through the screens (at 100% clean screen)

PLANT	THROUGH SCREEN HEADLOSSES (FT)					
	Multidisc (Aqseptence-Geiger)	Dual Flow (Ovivo)	Through Flow (SSI)	Dual Flow (Beaudrey AS)[1]	Modified Through Flow (Hydrolox)	Average HL (ft)
Labadie	0.21	1.2	0.14	0.66	0.5	0.54
Rush Island	0.42	1.23	0.17	0.66	0.75	0.65
Sioux	0.44	0.93	0.12	0.66	0.43	0.52

Notes:

1. Beaudrey AS screens are multi speed with drive speed increasing with increasing headloss. The headloss associated with starting the medium speed of the drive is listed in this table. The speed varies from low speed at 0.33 ft of headloss to the highest speed at 1.64 ft of headloss.

The comparison between the existing screen head loss and the average of the possible replacement screens headloss in included below in Table 1-2. For reference, the required horsepower per foot of head and the estimated annual energy consumption is also listed in the table. It should be cautioned that the pump curves are at a large scale relative to the very small head difference with relatively flat pump power curves in the area of the existing operating point. Therefore the estimated annual circulating energy may vary significantly from the value listed in the table and is highly dependent on the actual screen selected as the headloss for the different screen technologies varies significantly. Also, it should be remembered that any increase in headloss across the screen will cause a corresponding decrease in pump discharge which may be of greater significance than the estimated annual energy increase. As an example, for the Sioux circulating water pumps, an increase of screen headloss of 1 ft would decrease the pump discharge by approximately 1,800 gpm (1.4% decrease per pump) which may periodically restrict other operations when adequate cooling water is the limiting factor. (It is noted that this may be a short period per year).

Table 1-2 Comparison of Existing and Proposed Screen Headloss and Power requirements

PLANT	THROUGH SCREEN HEADLOSSES (FT)					
	Existing Screen Headloss[1]	Average Headloss for new screens	Circulating Water Pumps hp/ft head	Estimated Pump Power (hp)	Loss of Pump Capacity [3](gpm)	Estimated Annual Circulating Water Pump Energy (MWhr)[2]
Labadie	0.5	0.54	10	0.5	10000	21 MWhr/yr
Rush Island	0.5	0.65	20	2.4	1200	100 MWhr/yr
Sioux	0.5	0.52	23	1	200	21 MWhr/yr

Notes:

1. Headloss is based on the design screen start differential when known.
2. Estimated annual water pump energy in MWhr is based on an assumed capacity factor of 80% for the units they are cooling.
3. Loss of pump capacity is the loss of total pump capacity for all pumps. To determine the loss of capacity per pump, divide by the number of pumps at each intake.

Screen Manufacturer Quotations

Budgetary quotes were requested and received from five screen manufacturers (in alphabetical order); Aqseptence (Geiger), Beaudrey, Hydrolox, Ovivo, and SSI.

Three different screen types were proposed: through-flow, dual flow, and multi-disc. All proposals were for fish handling screens with provisions for a fish return system to meet the requirements of 316(b). All screens were sized to fit into the intake structure openings for the existing screens. However, it may be determined during detailed design that some screen designs may require some additional modification of the existing intake structures.

Screen suppliers were provided with basic sizing and design information for the intake screens at each plant upon which to base their proposals for replacement screens. Information provided included physical dimensions of the existing screens and screen slots in the intake structures, required flow, and range of water elevations. Suppliers were requested to provide responses including budgetary pricing, design information for required screen wash and fish removal water flows, design information for the fish return system, power requirements for screen drive motors, dimensioned drawings for screen units, summary of operating and maintenance requirements, and installation information. The quotes received are budgetary in nature, and are based on current day pricing. Prior to actual purchase, formal quotations will need to be requested, and detailed evaluation of each offering, including suitability of arrangement, operating impacts, operating costs, installation requirements, and balance of plant impacts will need to be conducted.

Screen mesh size or opening size is an important factor in selection of screens to provide the required entrainment protection for aquatic life. One of the studies required by the 316(b) rule, the 122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study, requires that the technical feasibility and incremental costs of various entrainment control technologies be evaluated, including fine-mesh screens with 2 mm or smaller openings. However, the actual opening size required and ultimately accepted by the regulatory agencies will be dependent on the type, size, and life stages of aquatic life that require protection at the specific intake, as determined by other required studies, including the 122.22(r)(9) Entrainment Characterization Study.

Each screen manufacturer based their offerings on screen opening sizes they believe will meet the 316(b) requirements. The sizes proposed by each of the manufacturers are as follows:

Aqseptence (Geiger)	3/8” (9.5 mm) diameter
Beaudrey	3/8” x 3/8” (9.5 mm x 9.5 mm)
Hydrolox	3/8” (9.5 mm)*
Ovivo	.08” x .08” (1.96 mm x 1.96 mm)
SSI	¼” x ½” (6.4 mm x 12.7 mm)

*Can provide openings down to 1.75 mm for no change in price.

All vendors can provide screens with 2mm openings, and some can provide smaller openings, down to 0.5 mm, if required. Selection of the screen opening size requirements for each of the three Ameren plants will need to be finalized following completion of the entrainment studies for each plant.

The following summarizes the offerings from each manufacturer, along with Black & Veatch’s initial opinion of the likely benefits to Ameren provided by the advertised features of each design.

Aqseptence (Multi-disc - Geiger design)

Multi-disc screens have not traditionally been utilized to a great extent in the past for power plant water intake applications, but there have been an increasing number of installations over the last few years. Feedback from users is generally positive. The design of the Geiger screens prevents carryover of debris into the clean water side downstream of the screen. The manufacturer states that the screens have been developed as a low-maintenance technology, using corrosion-resistant materials and long-life components. Maintenance and replacement of components can all be done from the operating deck level without the need to dewater the intake. The bottom of the screen unit is equipped with a curved guide for the drive chain instead of a submerged foot shaft and sprockets as provided on older traditional traveling band screens. Geiger also incorporates some service-friendly features such as flushing device for sediment removal from bottom of frame and an integrated nozzle cleaning device which allows clearing of spray nozzles with screens in service.

It is Black & Veatch's opinion that the Geiger design and construction offer benefits in terms of reliable operation, ease of maintenance, and service life, as compared to traditional traveling band-type screens.

Beaudrey (Dual-flow)

Dual-flow screens provide somewhat greater flow area than through-flow screens for the same application. Similar to the multi-disc screens, the dual flow design prevents carryover of debris. Also similar to the multi-disc screen design, the Beaudrey screens use a curved guide at the bottom rather than submerged moving parts. The screens are constructed largely of epoxy-coated carbon steel components with stainless steel screens. Beaudrey states that the screens are low-maintenance and designed for long life. It was noted that the screen drive motors for the Beaudrey screens are much larger than drive motors for other manufacturer's offerings (30-35 hp vs 5-20 hp).

Based on the information provided with the budgetary quote, we believe that Beaudrey's design features that eliminate the submerged lower shaft and sprockets should offer worthwhile advantages over a traditional band type traveling screen. However, further investigation including checking with current users would be needed to provide an opinion regarding the other features that Beaudrey notes. Also, the larger screen drive motor requirement is a concern.

Hydrolox (Modified through-flow)

Hydrolox engineered polymer traveling water screens are a variation on traditional through-flow band screens incorporating several proprietary design features. The polymer material used for the screen panels presents reduced risk of biofouling and ice adhesion, as well as eliminating corrosion issues. The frame is constructed from coated carbon steel with stainless steel side panels. Drive for the screen does not include chains as other designs do, but uses sprockets to directly engage the screen panels. There is no submerged lower shaft. The screens are said to be designed for long life and low maintenance. All maintenance can be performed at operating deck level, eliminating the need to remove the screen or dewater the intake. Similar to the Geiger screens, Hydrolox units have not been used to the extent of traditional traveling screens for power plant water intake applications, but there are a number of units that now have significant time in-service to begin to establish a track record, with positive user feedback. The unique design for fish and debris removal tilts the top of the screen unit back (away from the river side), which requires more space on that side of the screen than other designs.

Our opinion is that the Hydrolox design and construction offers benefits with regard to long life and ease of maintenance. The only potential drawback we note in the design would be the additional space required on the back side of the screens for the fish and debris removal systems. This would be of particular concern at the Sioux plant because of the proximity of the screens to platform steel and other equipment.

Ovivo (Dual-flow)

The screens offered by Ovivo are traditional dual-flow band screens with certain updates to improve operation and maintenance. Significant improvements include elimination of the submerged foot shaft and sprockets, decreased power requirements for drive motors, increased size of critical pins, rollers, and other moving components, shaft mounted drive and relocation of chain tensioning for accessibility from the operating deck. The screen units are mostly coated carbon steel construction with stainless steel screen panels. Ovivo included an extensive list of reference installations.

Ovivo’s design improves on the traditional traveling band screen configuration primarily with regard to elimination of the submerged lower shaft and sprockets and reduced drive motor power requirements. The other design features that Ovivo points out appear to be appropriate for improving operation and reliability. The fact that Ovivo is able to provide the lengthy reference list points toward good acceptance by purchasers, but the basic design has been available for a long time, so it would be worthwhile to confirm with Ovivo which references are for the current version of the design.

SSI (Through-flow)

The SSI screens are traditional through-flow band screen design with some updates for improved operation and maintenance. The materials of construction are carbon steel, with stainless steel screen material and FRP frames. Unlike the other proposed screen designs, the SSI configuration still includes a submerged lower shaft and sprockets. The carrier chain is a non-lubricated design for extended life. The SSI design requires considerably more water for debris removal and fish removal than most of the other offerings.

Because of the water velocity and overall length of the screen assemblies, SSI's design requires a submerged foot shaft and sprockets as well as a center basket backup beam. Because of these features our opinion is that the operation, maintenance, and reliability of these screens would be similar to that of the existing screens. The large water requirement for fish removal and debris removal would increase overall operating costs as compared with the offerings from other manufacturers.

A summary of advantage and disadvantages of the proposed screens are shown in Table 1-3

Table 1-3 Summary of Advantages and Disadvantages of Each Screen Manufacturer

	ADVANTAGES AND DISADVANTAGES OF PROPOSE SCREENS				
Screens	**Multidisc (Aqseptence-Geiger)**	**Dual Flow (Ovivo)**	**Thru Flow (SSI)**	**Dual Flow (Beaudrey AS)**	**Modified Thru Flow (Hydrolox)**
Advantages	• Design and construction features indicate probability of reliable operation • Ease of maintenance (can be done from operating deck) • Potentially long service life, as compared to traditional traveling band-type screens • Second lowest capital cost	• No submerged lower shaft or sprockets • Low drive motor power	• Lowest capital cost	• No submerged lower shaft • Self-cleaning strainer built into spray pipe • "Very large" debris handling capacity[1] • "Exceptionally long lasting" chains[1]	• No submerged shaft • Low maintenance • Reduced biofouling • Reduced corrosion • Reduced ice adhesion • Maintenance performed from operating deck
Disadvantages	• Limited operating history[2]	• High capital cost	• Greater fish return water requirement, • Has submerged rotating parts	• Higher drive motor power	• High capital cost • Requires additional space for installation • Limited operating history[2]

Notes:

1. Additional advantages claimed by Beaudrey AS must be verified with current owners of these screens.
2. Limited operating history – these are newer designs and smaller number of screens in service as compared to more traditional screen designs

Conceptual Arrangements of the Screen Installations

In creating the screen conceptual arrangements, the through-flow design was selected as the basis for the figures as it is the most common arrangement among the five manufacturers. Additional work would be required for the dual flow screen arrangements as additional wall plates would be required, and potentially additional modifications in the channel to create adequate space for installation. The basic concept applied for all fish return pipes was to return the fish on the downstream side of the intake structure to reduce potential for fish being re-entrained in the cooling water intake. Each facility's arrangement will be discussed separately in the following paragraphs.

One concern with the fish return pipe is winter operation could cause ice problems in the exposed pipes. To prevent ice build up some source of heat needs to be added to the water or pipe. The most economical source of heat available to the fish return pipe is to mix in heater water from the power plant cooling system. Piping drawings indicated a heated water system is already present at each of the intakes to provide hot water in front of the screens to prevent ice. The fish return pipes would have a tap from the existing hot water system and either a thermostatically controlled valve to maintain water temperature high enough to prevent freezing, or a simple manual valve which can be locked in at least five positions.

A second concern with the fish return pipe is the plugging with debris, particularly in the area around the screens as the flow changes direction and combines from different screens. To facilitate inspection and maintenance, the fish return system inside the intake building is a fish return trough were the entire length of the trough has hinged covers which may be opened for inspection and cleaning (may be left open if splashing and fish jumping proves to be no issue). Once the fish return exits the building, there is a transition to a fish return pipe to prevent splashing over in bends, and prevent fish from jumping out of the fish return system. Additionally, the pipe will provide greater structural rigidity for spanning between supports which are significantly more expensive outside the building as they are much taller and each support requires a pile foundation.

Additional alternatives for returning fish to the river were considered for this cost opinion and include:

- A single 90 degree bend and steep slope with open top trough
- A series of concrete or steel boxes with low level outlets (a reversal of a typical fish ladder)
- Proprietary systems to transport fish with little water.

The alternatives for the fish return system were not selected as they either were too new to be proven, were primarily designed for taking fish from low elevation to high elevation, or could result in injury to the fish because of excessive velocity when they impact the river.

Labadie Conceptual Screen Installation Arrangement

The Labadie circulating water intake is located on the Missouri River and has a large variation in water levels from the low water to the flood elevation. The intake screen velocity is set based on the low water and the fish return trough is set at a minimum of 8 feet above the intake building's operating floor elevation to allow access to other equipment for operation and maintenance. A maximum pipe slope of 4% was selected to shorten the length of the fish return pipe as it must take the fish from elevation 502 to elevation 446 (low river water level). To avoid interference with the shipping channel, the fish return pipe is coiled around in an oval with a minimum bend radius of 8 feet to reduce potential plugging with debris. Galvanized steel columns support both the fish return pipe and the access stairs and walkways.

At the start and end of each bend in the fish return pipe, a hinged access hatch is planned to allow for maintenance in the event of debris plugging the bends. A conceptual level plan and sections views (Figures A-1 and A-2) have been generated to show the layout and are included in Appendix A.

Rush Island Conceptual Screen Installation Arrangement

The Rush Island circulating water intake is located on the Mississippi River and has a large variation in water levels from the low water to the flood elevation. The intake screen velocity is set based on the low water and the fish return trough is set at a minimum of 8 feet above the intake buildings operating floor elevation to allow access to other equipment for operation and maintenance. A maximum pipe slope of 4% was selected to shorten the length of the fish return pipe as it must take the fish from elevation 420 to elevation 356 (low river water level). To avoid interference with the shipping channel and coal unloading operations, the fish return pipe is coiled around in an oval with a minimum bend radius of 8 feet to reduce potential plugging with debris. Galvanized steel columns support both the fish return pipe and the access stairs and walkways. At the start and end of each bend in the fish return pipe, a hinged access hatch is planned to allow for maintenance in the event of debris plugging the bends. A conceptual level plan and sections views (Figures A-3 and A-4) have been generated to show the layout and are included in Appendix A.

Sioux Conceptual Screen Installation Arrangement

The Sioux circulating water intake is located on the Mississippi River and has a large variation in water levels from the low water to the flood elevation. The intake screen velocity is set based on the low water and the fish return trough is set at a minimum of 8 feet above the intake buildings operating floor elevation to allow access to other equipment for operation and maintenance. The fish return pipe for Sioux differs from the Labadie and Rush Island plants in that it is planned to take the fish back to the Mississippi River by paralleling the intake channel. This arrangement allows fish to be returned to the river and not have to swim against the current of the intake channel. It was considered a possibility to return the fish to the circulating water outlet which would shorten the overall length of the fish return pipe, however the potential for thermal shock to the fish was the reason for not selecting this as the preferred arrangement. Because of the spatial layout to return fish to the Mississippi River, the pipe slope is set at 2% as it must take the fish from elevation 454 to elevation 416.5 (low river water level) over a length of approximately 1,800 feet. To avoid interference with the shipping channel and coal unloading operations, the fish return pipe will terminate near the shore of the river where at least 4 feet of water depth exists at the low river level. The fish return pipe will pass through the existing dike below grade and not have any bends when it is below grade as there will not be access for inspection and maintenance. Galvanized steel columns support both the fish return pipe and the access walkway where the fish return pipe is above grade. At the start of each bend in the fish return pipe, a hinged access hatch is planned to allow for maintenance in the event of debris plugging the bends. Long straight runs of pipe will have hinged access hatches spaced at approximately 50 foot intervals to facilitate inspection and cleaning of the pipe. A conceptual level plan and sections views (Figures A-5 through A-7) have been generated to show the layout and are included in Appendix A.

Budget Level Cost Opinions

Based on the conceptual layouts and budget level quotes provided by the manufacturers, a budget level cost opinion was prepared for each plant. A summary of the cost opinions for each plant is provided in Table 1-4. Additional details of the cost opinions are presented in Appendix B. Some of the basic assumptions utilized in the development of the cost opinion are listed below:

- Screens require minimal modification to the existing intake slot to allow installation (true for all but the dual flow type of screen).
- Outage costs are not included in the construction costs.
- Electrical costs are based on minimizing expense by limiting purchase of new equipment and materials and reducing installation labor where possible, including re-use of existing breakers, motor starters, and conductors where new equipment size or capacity is the same or smaller than the existing equipment.
- Screens are replaced two at a time (one single unit outage for the plant – or 4 screens at a time for single unit outage at Rush Island) in each year and require re-mobilization to the site for each pair of screens.
- Permitting and Owners engineering costs are estimated at 8% and 2% respectively. The permitting costs may vary significantly depending on special interests participation in the process.
- Fish return pipe is supported on drilled caisson piles to normal water level, then galvanized steel wide flanges with cross bracing above the normal water level.
- Fish return pipe is assumed to be thin walled stainless steel pipe designed to span between the supports when ½ full of water.
- Engineering for design through construction is 20% and Contingency is 30% for this conceptual level.

Table 1-4 Summary of Cost Opinions for Screen Installations

PLANT	LABADIE	RUSH ISLAND	SIOUX
Direct Construction Costs			
General Requirements	$458,000	$490,000	$220,000
Sitework Civil	$1,387,000	$1,380,000	$1,518,500
Electrical	$89,000	$16,000	$29,000
Screens	$6,514,000	$7,152,000	$2,496,500
Subtotal Direct Construction Cost	**$8,448,000**	**$9,038,000**	**$4,264,000**
Indirect Costs			
Owners E&A (2%)	$170,000	$180,000	$90,000
Permitting (8% of Direct Costs)	$680,000	$720,000	$340,000
Engineering (20% of Direct Costs)	$1,690,000	$1,810,000	$850,000
Subtotal Indirect Costs	**$2,540,000**	**$2,710,000**	**$1,280,000**
Subtotal Direct and Indirect Costs	**$10,988,000**	**$11,748,000**	**$5,544,000**
Contingencies (30%)	$3,300,000	$3,520,000	$1,660,000
ESTIMATED TOTAL PROJECT COST	**$14,288,000**	**$15,268,000**	**$7,204,000**

Overall EPC Delivery Cost Opinions

The EPC delivery cost estimate is based on execution of the project by a single contractor with responsibility for design, procurement of all materials and equipment, construction of the project, and commissioning and startup activities.

There are various ways the EPC activities can be executed, depending on how much of the work the EPC contractor self-performs versus engaging subcontractors to perform discrete portions of the workscope. The primary impact on the overall cost would be due to total markup, including the subcontractor's markup plus the EPC contractor's markup on the subcontractor's work.

For purposes of this estimate, it is assumed that the foundation (piles), supports, and fish return trough with access walkway would be subcontracted. This approach was chosen because of the specialty nature of drilling piles from a barge and the coordination of attaching the pipe and supports to the piles.

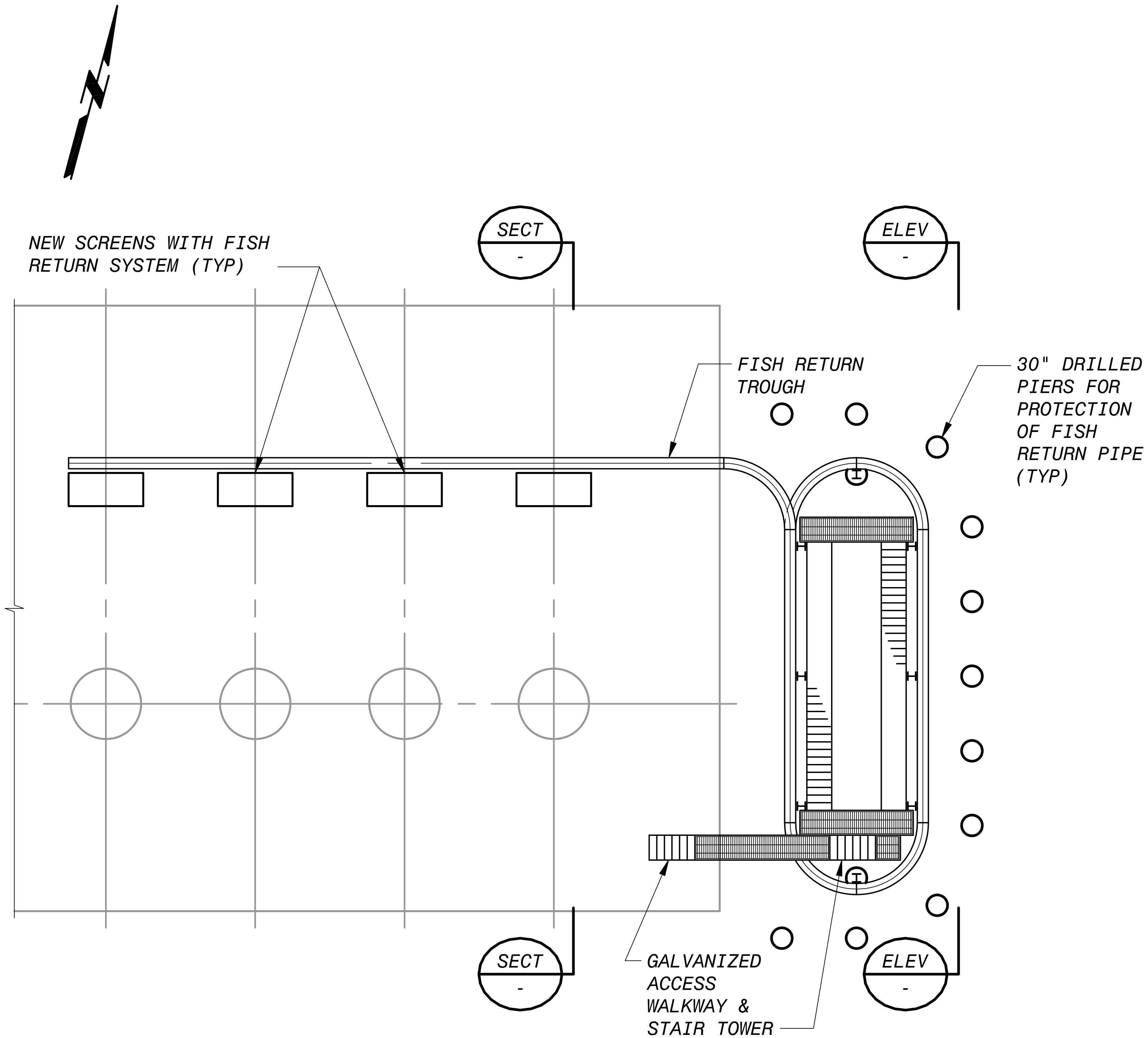
The remainder of the project work, including purchasing and installation of the screens, purchasing and installation of piping and electrical materials and equipment, and modifications to the intake structure, as well as oversight of the project are kept in the scope of the EPC Contractor. Schedule advantages of EPC contracting would be realized by including the design period with part of the construction period to shorten the overall project duration from start of design to operation. Table 1-5 provides the summary of the cost opinions for EPC delivery of the project.

Table 1-5 Summary of Cost Opinions for EPC Delivery of Screen Installations

PLANT	LABADIE	RUSH ISLAND	SIOUX
Direct Construction Costs			
General Requirements	$430,000	$462,000	$210,000
Sitework Civil	$1,352,000	$1,346,000	$1,491,500
Electrical	$89,000	$16,000	$29,000
Screens	$6,107,000	$6,705,000	$2,340,500
Subtotal Direct Construction Cost	**$7,978,000**	**$8,529,000**	**$4,071,000**
Indirect Costs			
Owners Contract Oversight (7%)	$560,000	$600,000	$280,000
Permitting (8% of Direct Costs)	$640,000	$680,000	$330,000
Engineering (15% of Direct Costs)	$1,200,000	$1,280,000	$610,000
Construction Management	$400,000	$200,000	$200,000
Subtotal Indirect Costs	**$2,800,000**	**$2,760,000**	**$1,420,000**
Subtotal Direct and Indirect Costs	**$10,778,000**	**$11,289,000**	**$5,491,000**
EPC Overhead and Profit (15%)	$1,617,000	$1,693,000	$824,000
Contingencies (30%)	$3,720,000	$3,890,000	$1,890,000
ESTIMATED TOTAL PROJECT COST	**$16,115,000**	**$16,872,000**	**$8,205,000**

APPENDIX A

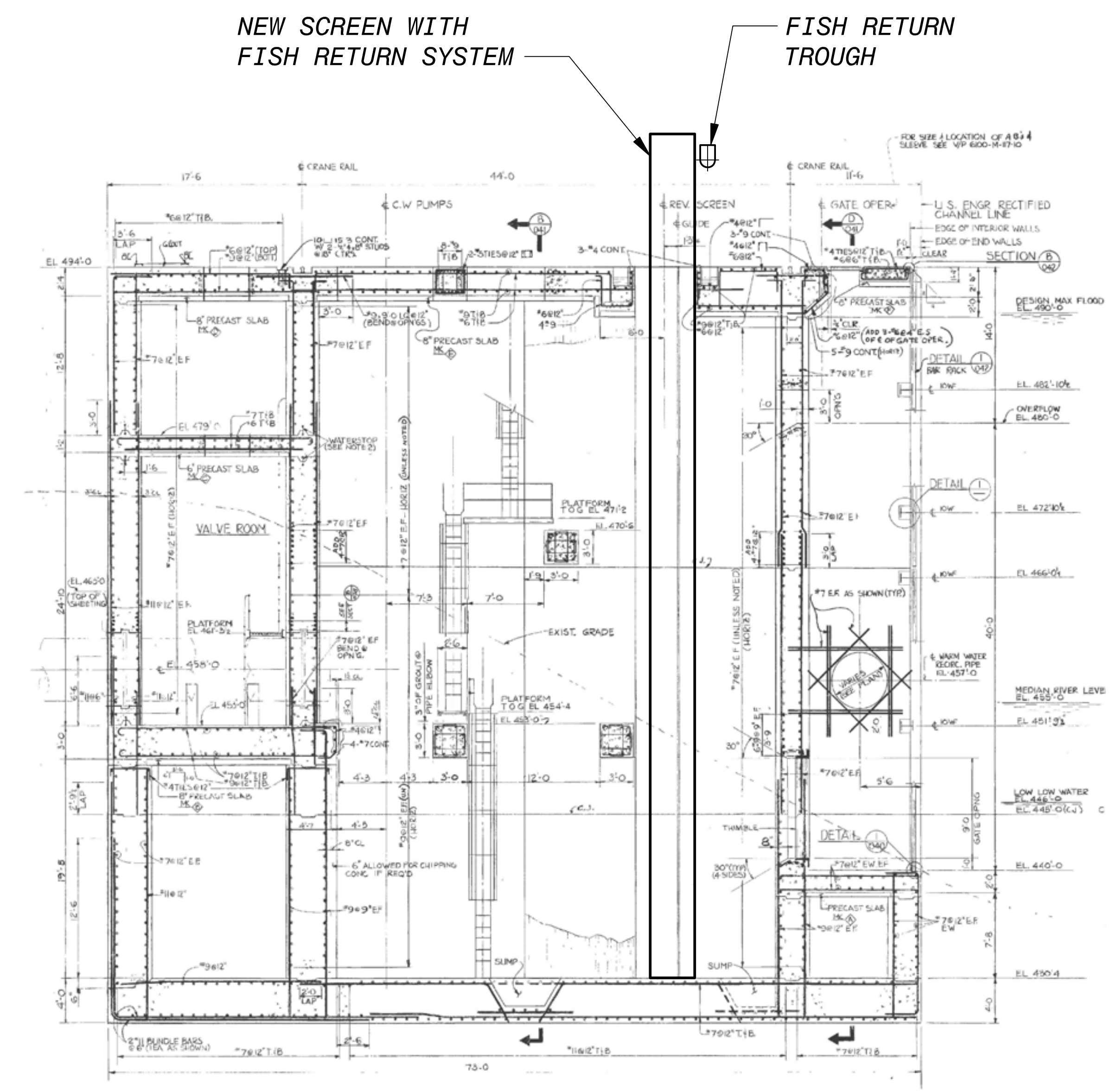
Conceptual Level Arrangement Figures



AMEREN LABADIE PLANT

FISH BYPASS - PLAN

1/16" = 1'-0"



AMEREN LABADIE PLANT

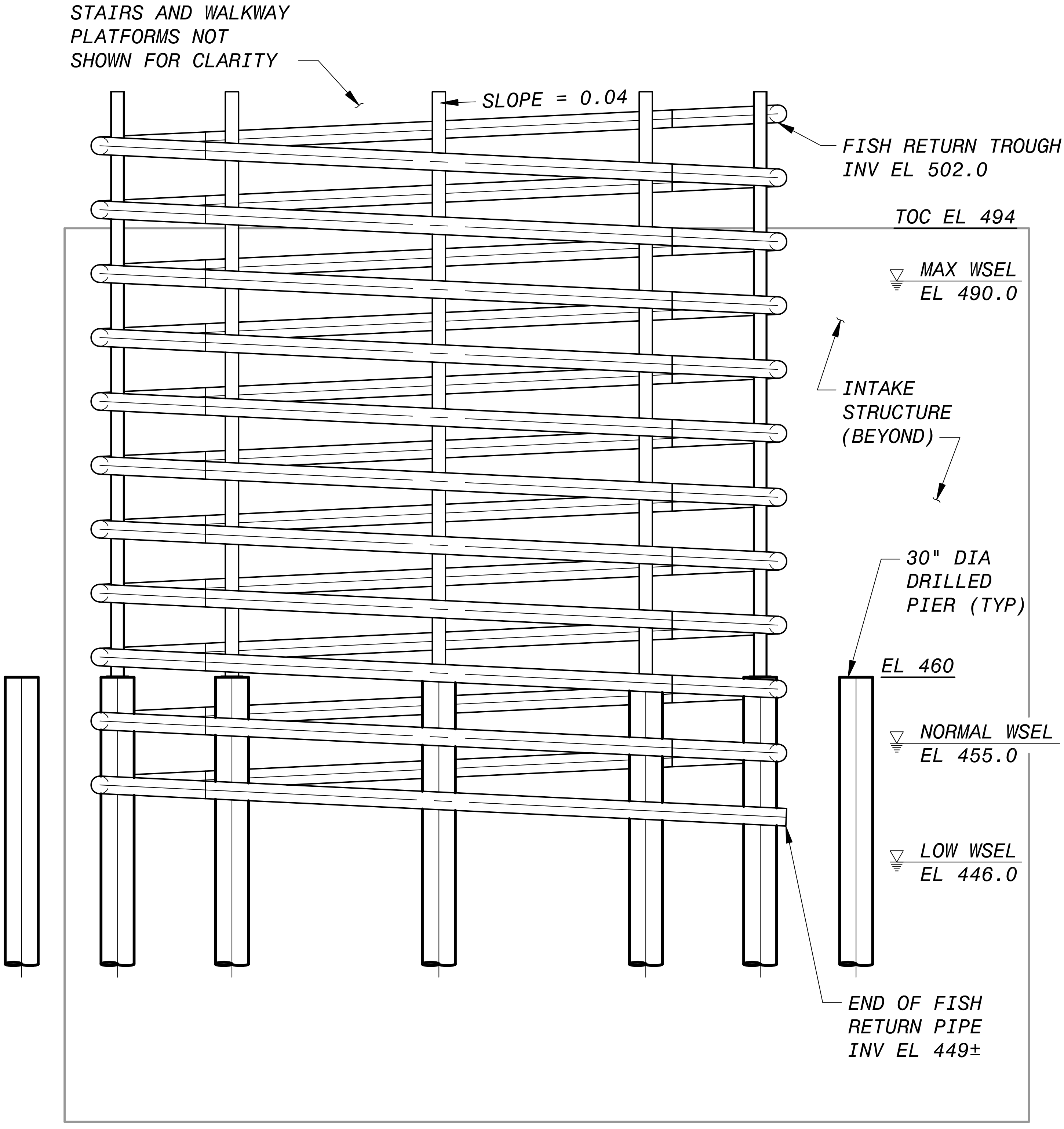
FISH BYPASS - SECTION

1/16" = 1'-0"

FIGURE A-1

16' 12' 8' 4' 0 16' 32'

1/16"=1'-0"



AMEREN LABADIE PLANT

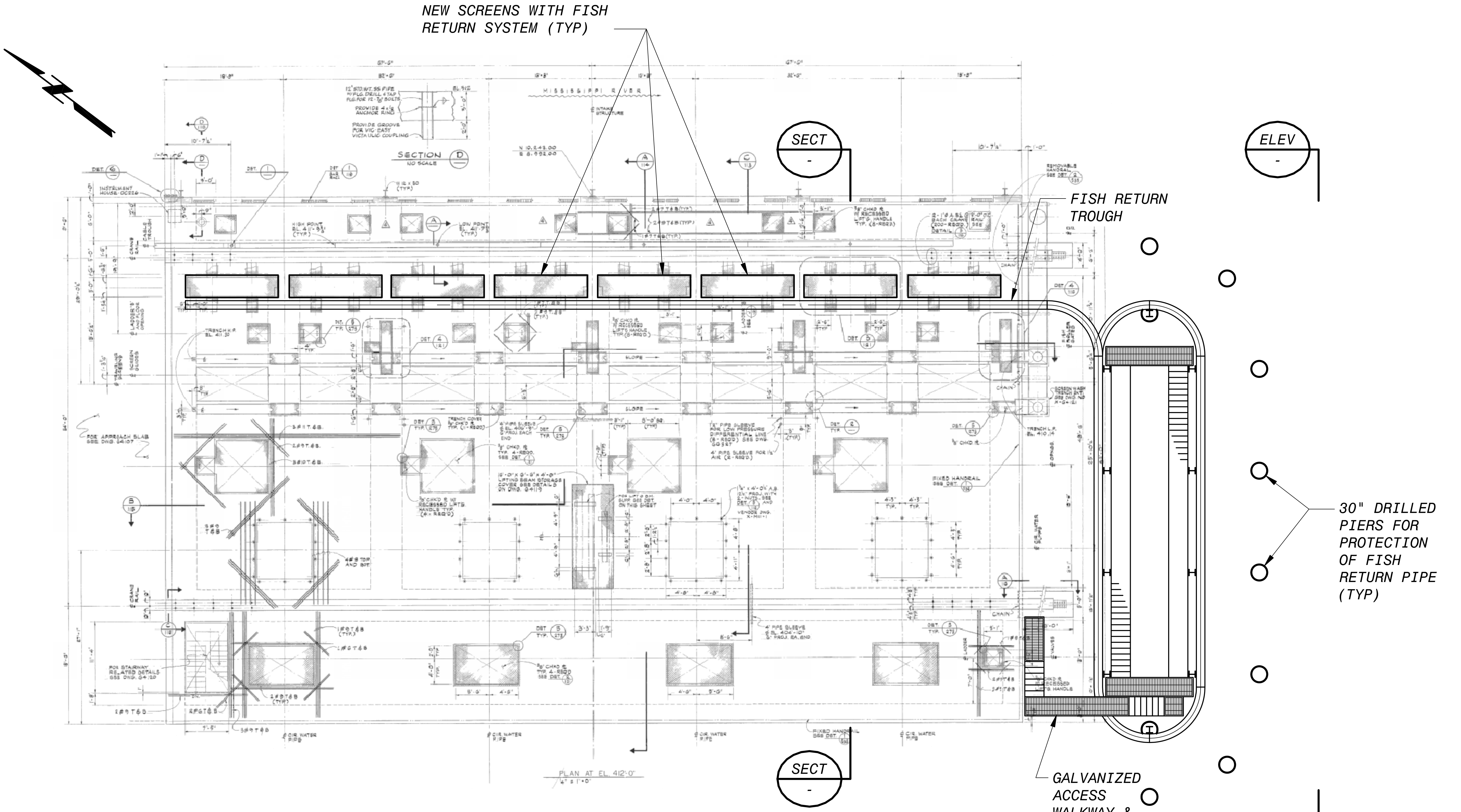
FISH BYPASS - ELEVATION

3/32" = 1'-0"

FIGURE A-2

12' 8' 4' 0 10' 20'

3/32"=1'-0"



AMEREN RUSH ISLAND PLANT

FISH BYPASS - PLAN

1/16" = 1'-0"

FIGURE A-3

16' 12' 8' 4' 0 16' 32'

1/16"=1'-0"

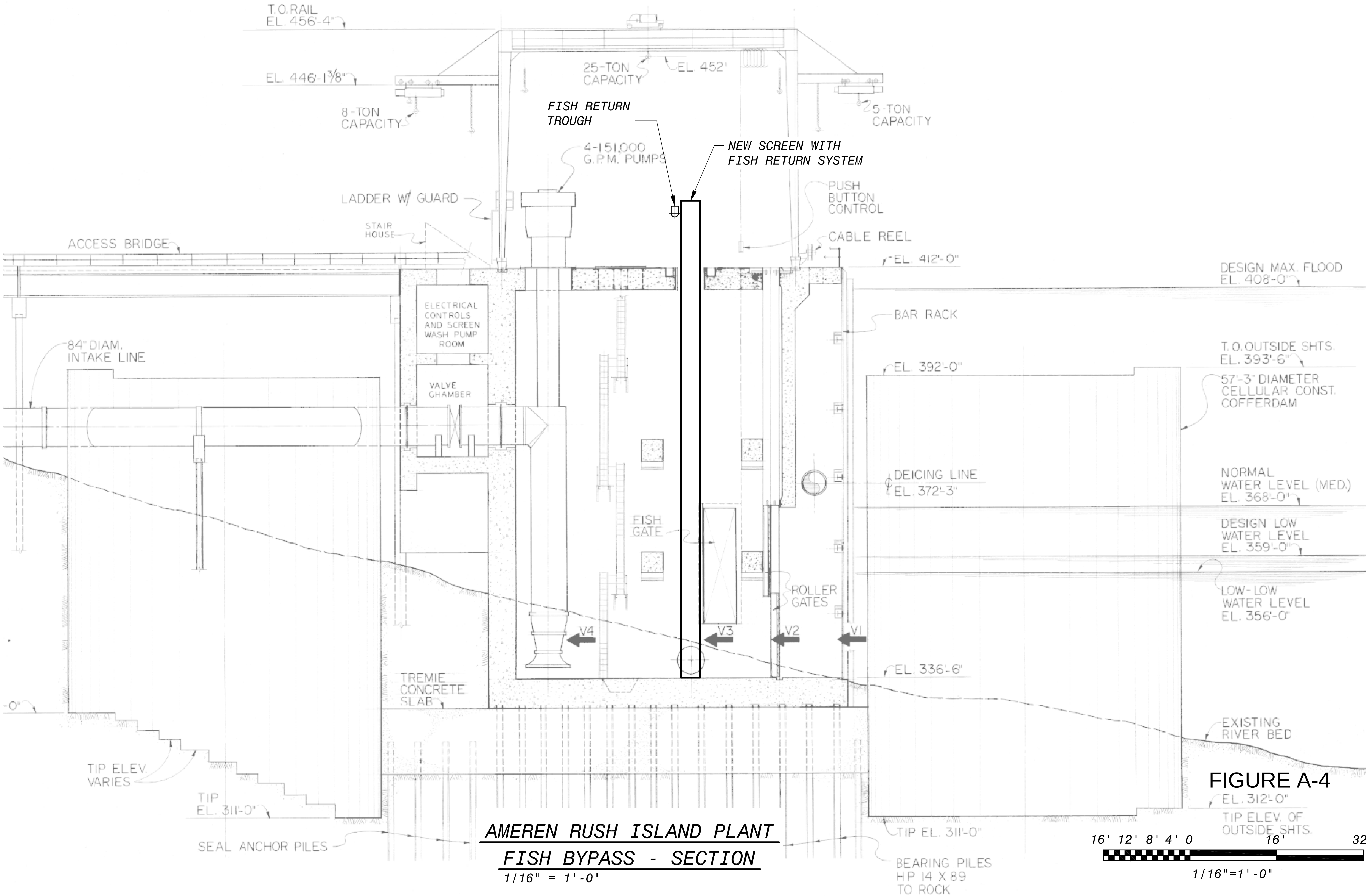
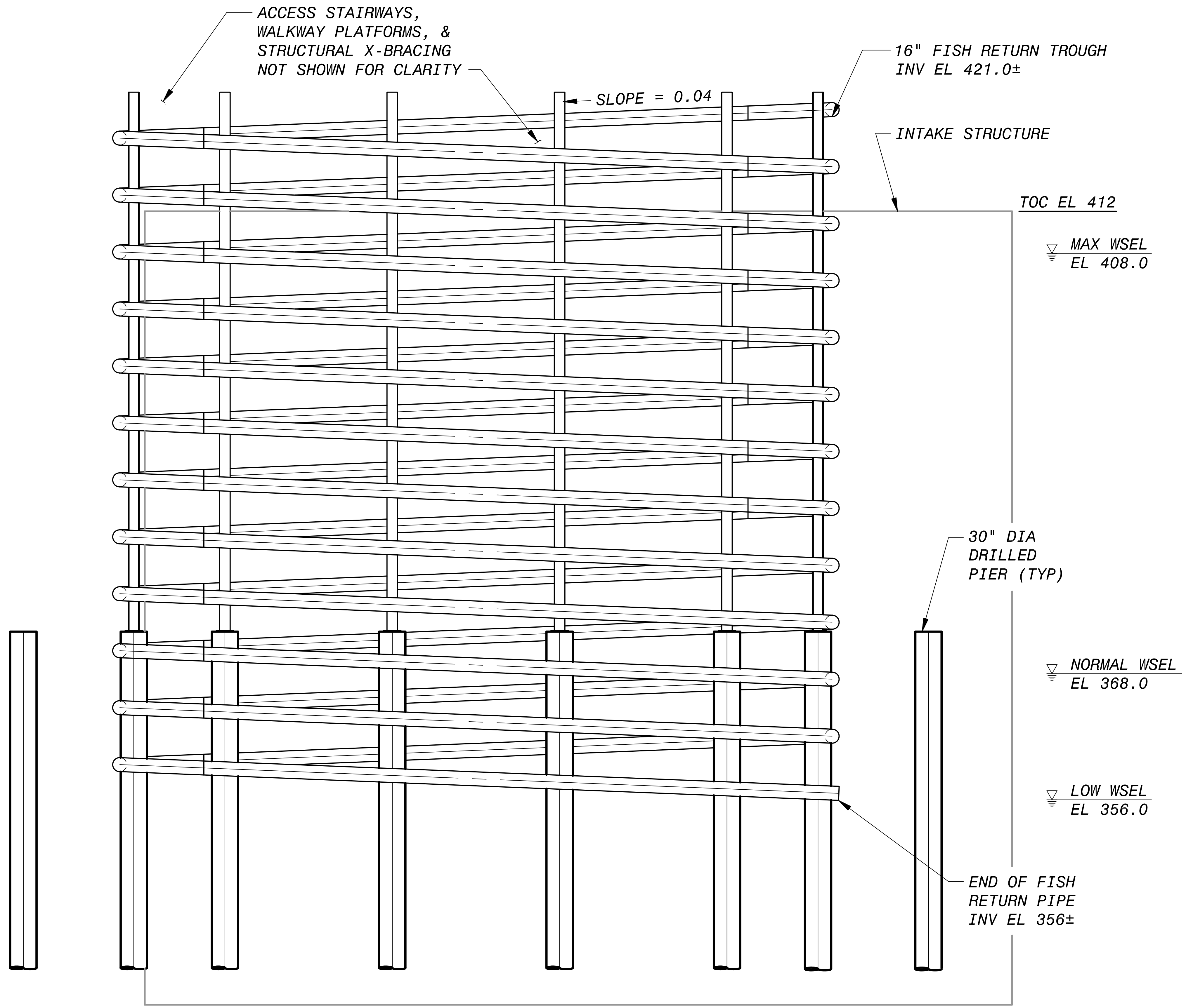


FIGURE A-4

AMEREN RUSH ISLAND PLANT

FISH BYPASS - SECTION

1/16" = 1'-0"

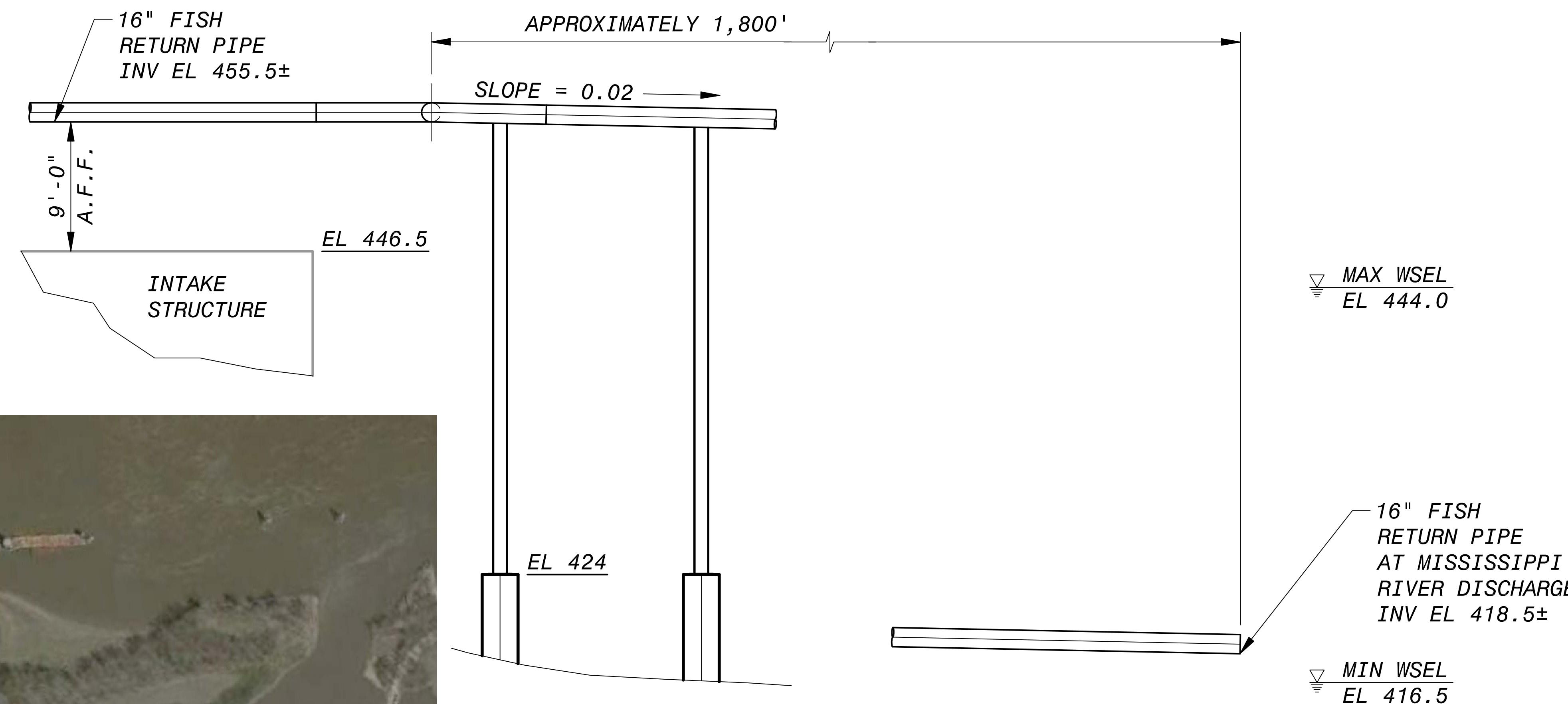


AMEREN RUSH ISLAND PLANT

FISH BYPASS - ELEVATION

3/32" = 1'-0"

FIGURE A-5



AMEREN SIOUX PLANT

FISH BYPASS - ELEVATION

3/32" = 1'-0"

AMEREN SIOUX PLANT

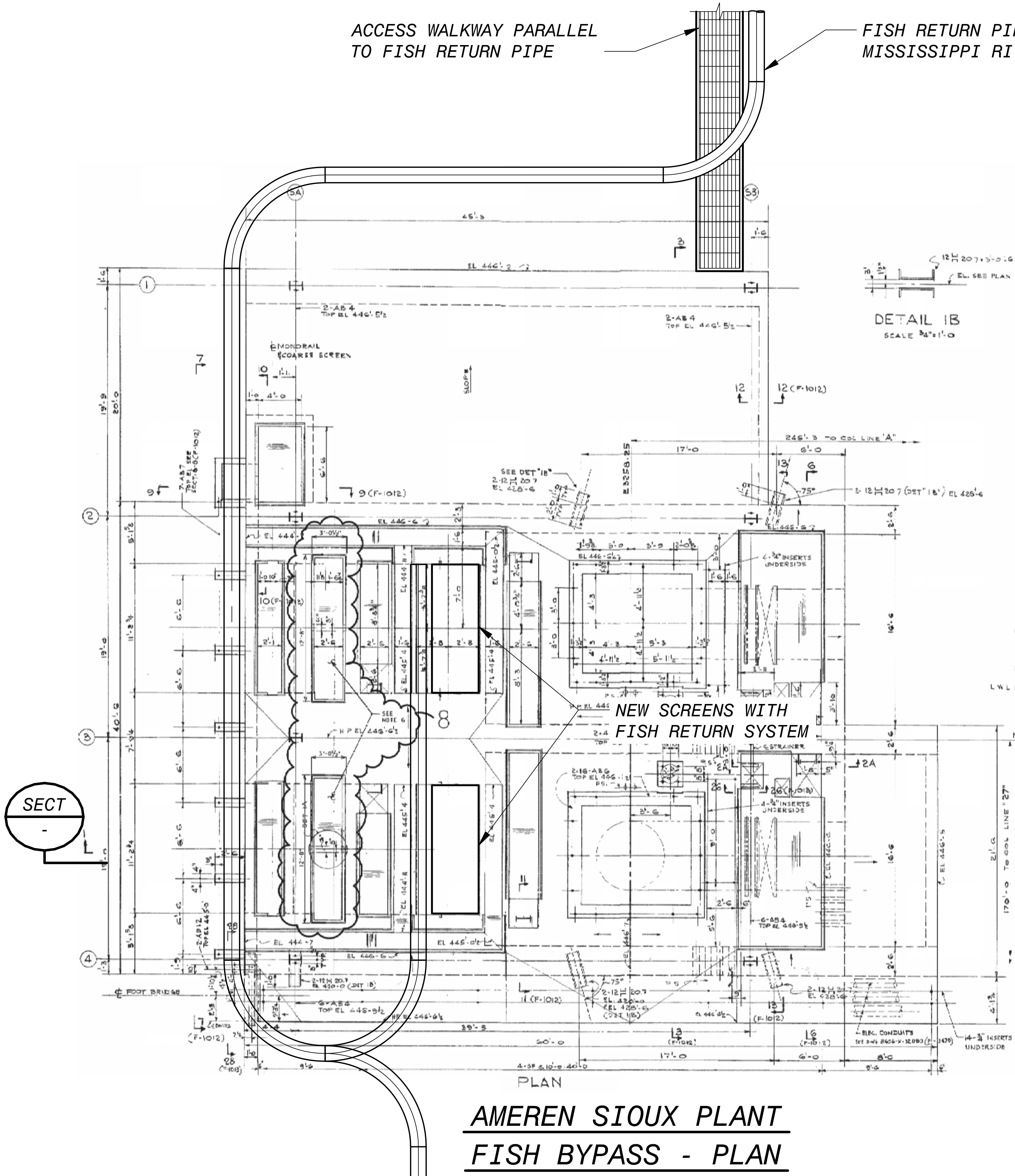
FISH BYPASS - OVERALL SITE PLAN

NO SCALE

FIGURE A-6

12' 8' 4' 0 10' 20'

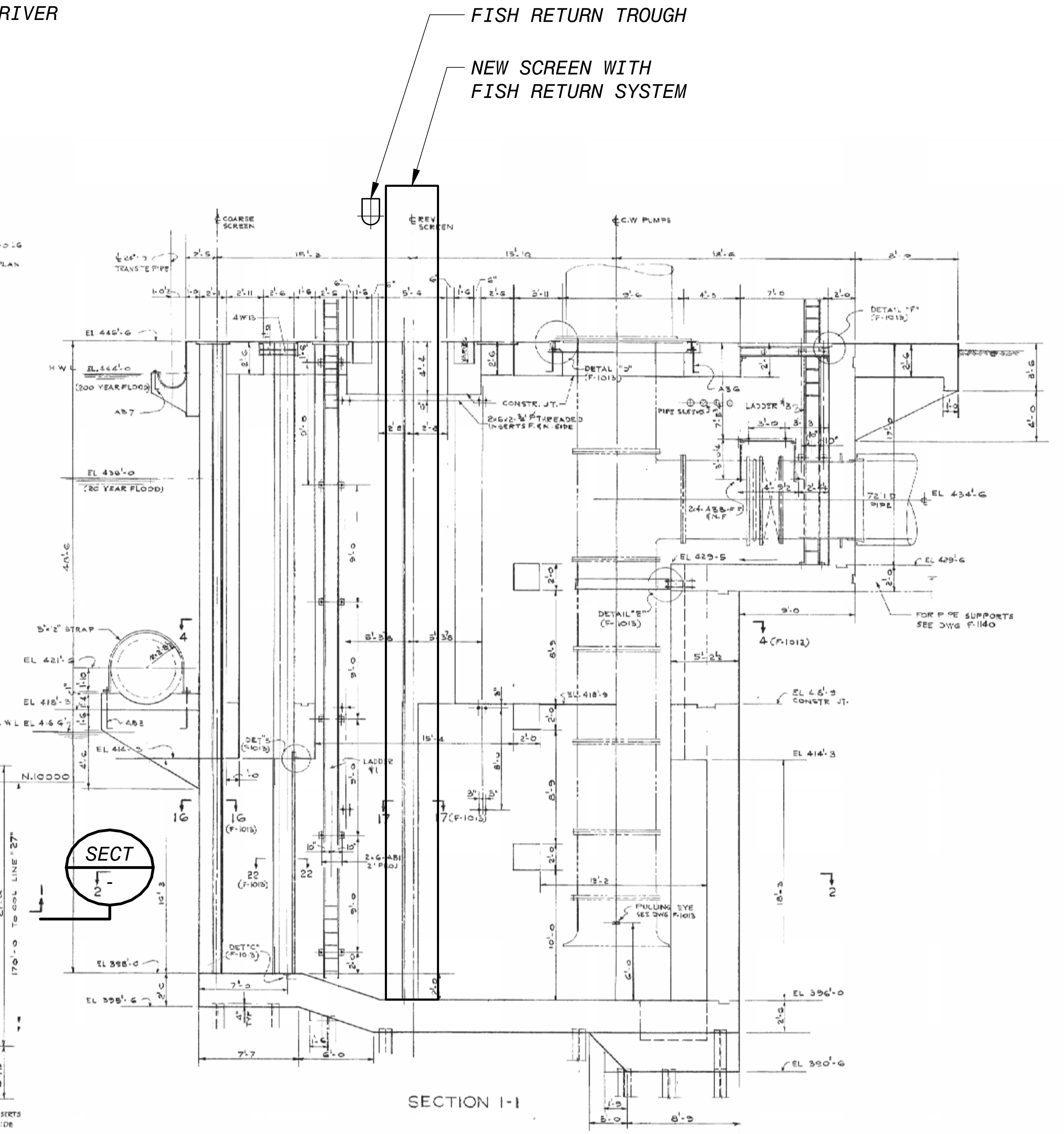
3/32"=1'-0"



AMEREN SIOUX PLANT

FISH BYPASS - PLAN

3/32" = 1'-0"



AMEREN SIOUX PLANT

FISH BYPASS - SECTION

3/32" = 1'-0"

12' 8' 4' 0 10' 20'

3/32"=1'-0"

FIGURE A-7

APPENDIX B-1

Conceptual Level Cost Opinions

Non EPC Delivery

BLACK & VEATCH
Corporation

8400 Ward Parkway, P.O. Box 8405, Kansas City, Missouri 64114, (913) 458-2000

B&V Project No. 193718

HIGH LEVEL CONCEPTUAL COSTS

Ameren
Saint Louis, MO

Labadie Powerplant New Traveling Screens with Fish Return System
Design Bid Build (Non EPC) Delivery

OPINION OF
PROBABLE CONSTRUCTION COST
October 14, 2016

SUMMARY

General Requirements		$458,000
Civil		$1,387,000
Electrical		$89,000
Screens		$6,514,000
	Subtotal Direct Costs	$8,448,000
Owners E&A	2%	$170,000
Permitting	8%	$680,000
Engineering	20%	$1,690,000
	Subtotal Indirect Costs	$2,540,000
	Total Direct and Indirect Costs	$10,988,000
Contingency	30%	$3,300,000
	Total	**$14,288,000**

BLACK & VEATCH

Location	St. Louis, MO
Client	Ameren
Project title	Labadie Power Plant Fish Screens
Probable Construction Cost	Non-EPC Delivery
Date	October 14, 2016
Page 2	

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
GENERAL REQUIREMENTS				
Mobilization		Lump Sum		58,000
Supervision		Lump Sum		160,000
Temporary facilities		Lump Sum		120,000
Temporary utilities		Lump Sum		80,000
Equipment rental & misc.		Lump Sum		40,000
Total - General Requirements				$458,000
CIVIL				
Remove existing traveling screens	8	EA	7,500	60,000
Modify existing debris troughs	1	LS	20,000	20,000
Repair damage to existing screen slots, install new guides if needed	8	EA	10,000	80,000
Fish Pumps - 2,000 gpm, 15-20 hp	2	EA	$15,000.00	30,000
Discharge piping - 10 inch diameter	60	ft	$100.00	6,000
Check valves - 10 inch diameter	2	EA	$3,200.00	6,400
Butterfly valves - 10 inch diameter	2	EA	2,200.00	4,400
Fish return trough/pipe - stainless steel	1,300	ft	427.61	555,900
Fish return pipe supports	8	EA	29,400.00	235,000
Access walkways	2,000	SF	20.00	40,000
Access stairs	14	EA	2,500.00	35,000
protective piles for fish return system	11	EA	26,300.00	289,300
Heated water to fish return pipe	1	LS	25,000.00	25,000
Total - Sitework Requirements			Subtotal	$1,387,000
ELECTRICAL				
Power supply and control modifications for new screen drives	1	LS	75,000	75,000
Control modifications for screen wash pumps	1	EA	1,000	1,000
Power supply and control modifications for new fish pumps	1	LS	13,000	13,000
			Subtotal	$89,000
SCREENS				
Manufacturer A: Ovivo (Dual-Flow Screens)	8	EA	730,175	5,841,400
Manufacturer B: Aqseptence (Geiger Multi-Disc Screens)	8	EA	456,000	3,648,000
Manufacturer C: Hydrolox (Nylon Thru-Flow Screens)	8	EA	761,226	6,089,800
Manufacturer D: SSI (through flow screens)	8	EA	289,820	2,318,600
Manufacturer E: Beaudrey (dual flow screens)	8	EA	307,323	2,458,600
Average				4,071,000
Installation - 60% of screen cost	1	LS	2,443,000	2,443,000
			Subtotal	$6,514,000

BLACK & VEATCH
Corporation

8400 Ward Parkway, P.O. Box 8405, Kansas City, Missouri 64114, (913) 458-2000

B&V Project No. 193718

HIGH LEVEL CONCEPTUAL COSTS

Ameren
Saint Louis, MO

Rush Island Powerplant New Traveling Screens with Fish Return System
Design Bid Build (Non EPC) Delivery

OPINION OF
PROBABLE CONSTRUCTION COST
October 14, 2016

SUMMARY

General Requirements		$490,000
Civil		$1,380,000
Electrical		$16,000
Screens		$7,152,000
	Subtotal Direct Costs	$9,038,000
Owners E&A	2%	$180,000
Permitting	8%	$720,000
Engineering	20%	$1,810,000
	Subtotal Indirect Costs	$2,710,000
	Total Direct and Indirect Costs	$11,748,000
Contingency	30%	$3,520,000
	Total	**$15,268,000**

BLACK & VEATCH

Location	St. Louis, MO
Client	Ameren
Project title	Rush Island Power Plant Fish Screens
Probable Construction Cost	Non-EPC Delivery
Date	October 14, 2016
Page 2	

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
GENERAL REQUIREMENTS				
Mobilization		Lump Sum		63,000
Supervision		Lump Sum		171,000
Temporary facilities		Lump Sum		128,000
Temporary utilities		Lump Sum		85,000
Equipment rental & misc.		Lump Sum		43,000
Total - General Requirements				$490,000
CIVIL				
Remove existing traveling screens	8	EA	7,500	60,000
Modify existing debris troughs	1	LS	20,000	20,000
Repair damage to existing screen slots, install new guides if needed	8	EA	10,000	80,000
Fish Pumps - 2,000 gpm, 20 hp	2	EA	$15,000.00	30,000
Discharge piping - 10 inch diameter	60	ft	$100.00	6,000
Check valves - 10 inch diameter	2	EA	$3,150.00	6,300
Butterfly valves - 10 inch diameter	2	EA	2,200.00	4,400
Fish return trough/pipe - stainless steel	1,300	ft	427.61	555,900
Fish return pipe supports	8	EA	38,400.00	307,000
Access walkways	2,000	SF	20.00	40,000
Access stairs	14	EA	2,500.00	35,000
protective piles for fish return system	8	EA	26,300.00	210,400
Heated water to fish return pipe	1	LS	25,000.00	25,000
Total - Sitework Requirements			Subtotal	$1,380,000
ELECTRICAL				
Power supply and control modifications for new screen drives	1	LS	5,500	6,000
Control modifications for screen wash pumps	1	EA	1,000	1,000
Power supply and control modifications for new fish pumps	1	LS	9,000	9,000
			Subtotal	$16,000
SCREENS				
Manufacturer A: Ovivo (Dual-Flow Screens)	8	EA	819,375	6,555,000
Manufacturer B: Aqseptence (Geiger Multi-Disc Screens)	8	EA	521,625	4,173,000
Manufacturer C: Hydrolox (Nylon Thru-Flow Screens)	8	EA	785,297	6,282,400
Manufacturer D: SSI (through flow screens)	8	EA	326,950	2,615,600
Manufacturer E: Beaudrey (dual flow screens)	8	EA	340,223	2,721,800
Average				4,470,000
Installation - 60% of screen cost	1	LS	2,682,000	2,682,000
			Subtotal	$7,152,000

BLACK & VEATCH
Corporation

8400 Ward Parkway, P.O. Box 8405, Kansas City, Missouri 64114, (913) 458-2000

B&V Project No. 193718

HIGH LEVEL CONCEPTUAL COSTS

Ameren
Saint Louis, MO

Sioux Powerplant New Traveling Screens with Fish Return System
Design Bid Build (Non EPC) Delivery

OPINION OF
PROBABLE CONSTRUCTION COST
October 14, 2016

SUMMARY

General Requirements		$220,000
Civil		$1,518,500
Electrical		$29,000
Screens		$2,496,500
	Subtotal Direct Costs	$4,264,000
Owners E&A	2%	$90,000
Permitting	8%	$340,000
Engineering	20%	$850,000
	Subtotal Indirect Costs	$1,280,000
	Total Direct and Indirect Costs	$5,544,000
Contingency	30%	$1,660,000
Total		$7,204,000

BLACK & VEATCH

Location	St. Louis, MO
Client	Ameren
Project title	Sioux Power Plant Fish Screens
Probable Construction Cost	Non-EPC Delivery
Date	October 14, 2016
Page 2	

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
GENERAL REQUIREMENTS				
Mobilization		Lump Sum		18,000
Supervision		Lump Sum		81,000
Temporary facilities		Lump Sum		61,000
Temporary utilities		Lump Sum		40,000
Equipment rental & misc.		Lump Sum		20,000
Total - General Requirements				$220,000
CIVIL				
Remove existing traveling screens	4	EA	7,500	30,000
Modify existing debris troughs	1	LS	10,000	10,000
Repair damage to existing screen slots, install new guides if needed	4	EA	10,000	40,000
Fish Pumps - 2,000 gpm, 20 hp	2	EA	$15,000.00	30,000
Discharge piping - 10 inch diameter	60	ft	$100.00	6,000
Check valves - 10 inch diameter	2	EA	$3,150.00	6,300
Butterfly valves - 10 inch diameter	2	EA	2,200.00	4,400
Fish return trough/pipe - stainless steel	1,800	ft	299.32	538,800
Access walkway	5,400	sf	20.00	108,000
Fish return pipe supports	60	EA	11,500.00	690,000
Heated water to fish return pipe	1	LS	25,000.00	25,000
Additional screen wash pump (100 hp)	1	EA	30,000.00	30,000
Total - Sitework Requirements			Subtotal	$1,518,500
ELECTRICAL				
Power supply and control modifications for new screen drives	1	LS	3,000	3,000
Power supply for new screen wash pump and controls modifications	1	LS	19,000	19,000
Power supply and controls for new fish pumps	1	LS	6,500	7,000
			Subtotal	$29,000
SCREENS				
Manufacturer A: Ovivo (Dual Flow Screens)	4	EA	502,250	2,009,000
Manufacturer B: Aqseptence (Geiger Multi-Disc Screens)	4	EA	429,500	1,718,000
Manufacturer C: Hydrolox (Nylon Thru-Flow Screens)	4	EA	450,329	1,801,300
Manufacturer D: SSI (through flow screens)	4	EA	272,300	1,089,200
Manufacturer E: Beaudrey (dual flow screens)	4	EA	295,980	1,183,900
Average				1,560,300
Installation - 60% of screen cost	1	LS	936,180	936,200
			Subtotal	$2,496,500

APPENDIX B-2

Conceptual Level Cost Opinions

EPC Delivery

BLACK & VEATCH
Corporation

8400 Ward Parkway, P.O. Box 8405, Kansas City, Missouri 64114, (913) 458-2000

B&V Project No. 193718

HIGH LEVEL CONCEPTUAL COSTS

Ameren
Saint Louis, MO

Labadie Powerplant New Traveling Screens with Fish Return System
For EPC Project Delivery

OPINION OF
PROBABLE CONSTRUCTION COST
October 14, 2016

SUMMARY

General Requirements		$430,000
Civil		$1,352,000
Electrical		$89,000
Screens		$6,107,000
	Subtotal Direct Costs	$7,978,000
Owners Contract Oversight Costs	7%	$560,000
Permitting	8%	$640,000
Engineering	15%	$1,200,000
Construction Management		$400,000
	Subtotal Indirect Costs	$2,800,000
	Total Direct and Indirect Costs	$10,778,000
EPC Overhead & Profit	15%	$1,617,000
	Subtotal	$12,395,000
Contingency	30%	$3,720,000
	Total	**$16,115,000**

BLACK & VEATCH

Location	St. Louis, MO
Client	Ameren
Project title	Labadie Power Plant Fish Screens
Probable Construction Cost	For EPC Project Delivery
Date	October 14, 2016
Page 2	

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
GENERAL REQUIREMENTS				
Mobilization		Lump Sum		53,000
Supervision		Lump Sum		151,000
Temporary facilities		Lump Sum		113,000
Temporary utilities		Lump Sum		75,000
Equipment rental & misc.		Lump Sum		38,000
Total - General Requirements				$430,000
CIVIL				
Remove existing traveling screens	8	EA	6,400	51,200
Modify existing debris troughs	1	LS	17,000	17,000
Repair damage to existing screen slots, install new guides if needed	8	EA	8,500	68,000
Fish Pumps - 2,000 gpm, 15-20 hp	2	EA	$12,750.00	25,500
Discharge piping - 10 inch diameter	60	ft	$85.00	5,100
Check valves - 10 inch diameter	2	EA	$2,750.00	5,500
Butterfly valves - 10 inch diameter	2	EA	1,800.00	3,600
Fish return trough/pipe - stainless steel	1,300	ft	427.61	555,900
Fish return pipe supports	8	EA	29,400.00	235,200
Access walkways	2,000	SF	20.00	40,000
Access stairs	14	EA	2,500.00	35,000
protective piles for fish return system	11	EA	26,300.00	289,000
Heated water to fish return pipe	1	LS	21,000.00	21,000
Total - Sitework Requirements			Subtotal	$1,352,000
ELECTRICAL AND CONTROL				
Power supply and control modifications for new screen drives	1	LS	75,000	75,000
Control modifications for screen wash pumps	1	EA	1,000	1,000
Power supply and control modifications for new fish pumps	1	LS	13,000	13,000
			Subtotal	$89,000
SCREENS				
Manufacturer A: Ovivo (Dual-Flow Screens)	8	EA	730,175	5,841,400
Manufacturer B: Aqseptence (Geiger Multi-Disc Screens)	8	EA	456,000	3,648,000
Manufacturer C: Hydrolox (Nylon Thru-Flow Screens)	8	EA	761,226	6,089,800
Manufacturer D: SSI (through flow screens)	8	EA	289,820	2,318,600
Manufacturer E: Beaudrey (dual flow screens)	8	EA	307,323	2,458,600
Average				4,071,000
Installation - 50% of screen cost	1	LS	2,036,000	2,036,000
			Subtotal	$6,107,000

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Corporation

8400 Ward Parkway, P.O. Box 8405, Kansas City, Missouri 64114, (913) 458-2000

B&V Project No. 193718

HIGH LEVEL CONCEPTUAL COSTS

Ameren
Saint Louis, MO

Rush Island Powerplant New Traveling Screens with Fish Return System
For EPC Project Delivery

OPINION OF
PROBABLE CONSTRUCTION COST
October 14, 2016

SUMMARY

General Requirements		$462,000
Civil		$1,346,000
Electrical		$16,000
Screens		$6,705,000
	Subtotal Direct Costs	$8,529,000
Owners Contract Oversight Cost	7%	$600,000
Permitting	8%	$680,000
Engineering	15%	$1,280,000
Construction Management		$200,000
	Subtotal Indirect Costs	$2,760,000
	Total Direct and Indirect Costs	$11,289,000
EPC Overhead & Profit	15%	$1,693,000
	Subtotal	$12,982,000
Contingency	30%	$3,890,000
	Total	**$16,872,000**

BLACK & VEATCH

Location	St. Louis, MO
Client	Ameren
Project title	Rush Island Power Plant Fish Screens
Probable Construction Cost	For EPC Project Delivery
Date	October 14, 2016
Page 2	

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
GENERAL REQUIREMENTS				
Mobilization		Lump Sum		59,000
Supervision		Lump Sum		161,000
Temporary facilities		Lump Sum		121,000
Temporary utilities		Lump Sum		81,000
Equipment rental & misc.		Lump Sum		40,000
Total - General Requirements				$462,000
CIVIL				
Remove existing traveling screens	8	EA	6,400	51,200
Modify existing debris troughs	1	LS	17,000	17,000
Repair damage to existing screen slots, install new guides if needed	8	EA	8,500	68,000
Fish Pumps - 2,000 gpm, 20 hp	2	EA	$13,000.00	26,000
Discharge piping - 10 inch diameter	60	ft	$85.00	5,100
Check valves - 10 inch diameter	2	EA	$2,750.00	5,500
Butterfly valves - 10 inch diameter	2	EA	1,850.00	3,700
Fish return trough/pipe - stainless steel	1,300	ft	427.61	555,900
Fish return pipe supports	8	EA	38,400.00	307,200
Access walkways	2,000	SF	20.00	40,000
Access stairs	14	EA	2,500.00	35,000
protective piles for fish return system	8	EA	26,300.00	210,400
Heated water to fish return pipe	1	LS	21,000.00	21,000
Total - Sitework Requirements			Subtotal	$1,346,000
ELECTRICAL AND CONTROL				
Power supply and control modifications for new screen drives	1	LS	5,500	6,000
Control modifications for screen wash pumps	1	EA	1,000	1,000
Power supply and control modifications for new fish pumps	1	LS	9,000	9,000
			Subtotal	$16,000
SCREENS				
Manufacturer A: Ovivo (Dual-Flow Screens)	8	EA	819,375	6,555,000
Manufacturer B: Aqseptence (Geiger Multi-Disc Screens)	8	EA	521,625	4,173,000
Manufacturer C: Hydrolox (Nylon Thru-Flow Screens)	8	EA	785,297	6,282,400
Manufacturer D: SSI (through flow screens)	8	EA	326,950	2,615,600
Manufacturer E: Beaudrey (dual flow screens)	8	EA	340,223	2,721,800
Average				4,470,000
Installation - 50% of screen cost	1	LS	2,235,000	2,235,000
			Subtotal	$6,705,000

BLACK & VEATCH
Corporation

8400 Ward Parkway, P.O. Box 8405, Kansas City, Missouri 64114, (913) 458-2000

B&V Project No. 193718

HIGH LEVEL CONCEPTUAL COSTS

Ameren
Saint Louis, MO

Sioux Powerplant New Traveling Screens with Fish Return System
For EPC Project Delivery

OPINION OF
PROBABLE CONSTRUCTION COST
October 14, 2016

SUMMARY

General Requirements		$210,000
Civil		$1,491,500
Electrical		$29,000
Screens		$2,340,500
	Subtotal Direct Costs	$4,071,000
Owners Contract Oversight Cost	7%	$280,000
Permitting	8%	$330,000
Engineering	15%	$610,000
Construction Management		$200,000
	Subtotal Indirect Costs	$1,420,000
	Total Direct and Indirect Costs	$5,491,000
EPC Overhead & Profit	15%	$824,000
	Subtotal	$6,315,000
Contingency	30%	$1,890,000
Total		$8,205,000

BLACK & VEATCH

Location	St. Louis, MO
Client	Ameren
Project title	Sioux Power Plant Fish Screens
Probable Construction Cost	For EPC Project Delivery
Date	October 14, 2016
Page 2	

Item Description	Quantity	Unit	Unit Cost $	Total Cost $
GENERAL REQUIREMENTS				
Mobilization		Lump Sum		17,000
Supervision		Lump Sum		77,000
Temporary facilities		Lump Sum		58,000
Temporary utilities		Lump Sum		39,000
Equipment rental & misc.		Lump Sum		19,000
Total - General Requirements				$210,000
CIVIL				
Remove existing traveling screens	4	EA	6,500	26,000
Modify existing debris troughs	1	LS	8,500	8,500
Repair damage to existing screen slots, install new guides if needed	4	EA	8,500	34,000
Fish Pumps - 2,000 gpm, 20 hp	2	EA	$13,000.00	26,000
Discharge piping - 10 inch diameter	60	ft	$85.00	5,100
Check valves - 10 inch diameter	2	EA	$2,700.00	5,400
Butterfly valves - 10 inch diameter	2	EA	1,850.00	3,700
Fish return trough/pipe - stainless steel	1,800	ft	299.32	538,800
Access walkway	5,400	sf	20.00	108,000
Fish return pipe supports	60	EA	11,500.00	690,000
Heated water to fish return pipe	1	LS	21,000.00	21,000
Additional screen wash pump (100 hp)	1	EA	25,000.00	25,000
Total - Sitework Requirements			Subtotal	$1,491,500
ELECTRICAL AND CONTROL				
Power supply and control modifications for new screen drives	1	LS	3,000	3,000
Power supply for new screen wash pump and controls modifications	1	LS	19,000	19,000
Power supply and controls for new fish pumps	1	LS	6,500	7,000
			Subtotal	$29,000
SCREENS				
Manufacturer A: Ovivo (Dual Flow Screens)	4	EA	502,250	2,009,000
Manufacturer B: Aqseptence (Geiger Multi-Disc Screens)	4	EA	429,500	1,718,000
Manufacturer C: Hydrolox (Nylon Thru-Flow Screens)	4	EA	450,329	1,801,300
Manufacturer D: SSI (through flow screens)	4	EA	272,300	1,089,200
Manufacturer E: Beaudrey (dual flow screens)	4	EA	295,980	1,183,900
Average				1,560,300
Installation - 50% of screen cost	1	LS	780,150	780,200
			Subtotal	$2,340,500

APPENDIX C

Manufacturer Provided Data and Quotations

1. Quote and Data from Aqseptence (Geiger)
2. Quote and Data from Beaudrey
3. Quote and Data from Hydrolox
4. Quote and Data from Ovivo
5. Quote and Data from SSI

Appendix 10 E. Veritas Economic Consulting – Social Costs of Purchasing and Installing Entrainment Reduction Technologies: Labadie Energy Center